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Conceptions of the Nature of Science and Technology: a Study with Children and Youths in a Non-Formal Science and Technology Education Setting

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Abstract This study investigated some of the aspects that characterise the understanding of the *Nature of Science* (*NOS*) and *Nature of Technology* (*NOT*) of 20 children and youths from different countries who perform scientific and technological activities in a non-formal teaching and learning setting. Data were collected using a questionnaire and semistructured interviews. A categorical instrument was developed to analyse the participants' conceptions of the following subjects: (1) the role of the scientist, (2) NOS and (3) NOT. The results suggest that the participants had naïve conceptions of NOS that are marked by empirical and technical-instrumental views. They characterised NOT primarily as an instrumental apparatus, an application of knowledge and something important that is part of their lives. They exhibited a stereotypical understanding of the role of the scientist (development of methods, demonstration of facts, relationship with technological devices, etc.).

Keywords Conceptions · Nature of science · Nature of technology · View of scientists · Science education · Non-formal education

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Introduction

Conceptions of the *Nature Of Science* (NOS) and the *Nature Of Technology* (NOT) remain a subject of debate in the fields of philosophy, sociology and science education (Constantinou et al. 2010; Lederman 1992, 2007; Lederman et al. 2002). Those concepts are difficult to define and sometimes lead to a lack of consensus (Driver et al. 1996; Lederman 2007); however, teachers and students' understanding of such concepts is considered relevant for understanding the features that characterise science and technology (Abd-El-Khalick et al. 2001; Bell and Lederman 2003; Lederman 2007).

With this study, it is our intention to participate on the aforementioned debate characterising some aspects mentioned. First, we address the idea that science and technology are two intimately related fields of human activity, i.e. that they are strongly interdependent (Bell and Lederman 2003). That strong connection notwithstanding, both fields represent clearly distinguishable domains of human action inasmuch as they serve different social purposes (Constantinou et al. 2010; Gil-Pérez et al. 2001; Gil-Pérez et al. 2005). In this regard, one might say that "science aims at producing reliable knowledge about how systems function; technology seeks to generate solutions to problems encountered by society or to develop procedures or products that meet human needs" (Constantinou et al. 2010, p. 145).

In addition to the conceptions of NOS and NOT, students also have different conceptions of the role of the scientist in society, such as stereotypical images (someone who performs research or attempts to invent a new product) and different features (symbols of research, knowledge symbols, technology) (Buldu 2006), negative aspects (Scherz and Oren 2006) and general descriptions (Buldu 2006; Newton and Newton 1998; Scherz and Oren 2006).

Although students' conceptions of the role of science, technology and the work of scientists have been widely investigated (Constantinou et al. 2010; Driver et al. 1996; Ferreira Gauchía et al. 2006; Gil-Pérez et al. 2005; Lederman 2007), most studies have analysed those conceptions separately

Thus, the aim of this study was to identify the conceptions, views and images[1] of science, technology and the scientist held by children and youths who perform scientific and technical activities in a non-formal teaching and learning setting. More specifically, we intend to provide answers to the following questions:

1. What are children and youths' conceptions of the role of the scientist in society?
2. What are children and youths' conceptions of NOS?
3. What are children and youths' conceptions of NOT?

Why study these three conceptions? Science education is too often limited to the acquisition of facts; technology education is too often limited to proficient use of technology (Kruse and Wilcox 2013). For many researchers in science education (Bell and Lederman 2003; Constantinou et al. 2010; Driver et al. 1996; Lederman 2007) to achieve greater science and technology literacy, they must understand the nature of both science and technology (NOST). Through the understanding of NOST, students can make better-informed personal decisions and participate in critical cultural discourse about the role of science and technology in their lives.

[1] Note that in this study, "conceptions", "images" or "views" refer to perceptions, prototypes or typical examples of a certain entity or venture. In other words, "images of students" about scientific or technological environments reflect their perceptions of these places and likely affect their attitudes (Scherz and Oren 2006).

Our assumption is that the findings of this research can be used to inform designing or modifying activity sequences that address these conceptions. The educational implication is that once initial perceptions are identified, researchers and teachers can provide meaningful experiences to contest the stereotypical images of science, technology and the scientist held by children and youths.

What Does the Literature Tell Us about the Conceptions of NOS, NOT and the Role of The Scientist?

Conceptions of the Role of the Scientist

The first conception of students that we would like to characterise is that of the role of the scientist in society. The image of the scientist in the eyes of students from various age groups has been the focus of several studies (Akerson and Abd-El-Khalick 2005; Buldu 2006; Driver et al. 1996; Kosminsky and Giordan 2002; Lederman 2007; Newton and Newton 1998; Scherz and Oren 2006).

A study by Scherz and Oren (2006) showed that students often have stereotypical images of scientists that influence their attitude towards science. In other words, scientists and scientific work are sometimes seen as unpleasant, restricted to the laboratory setting and exotic. Not only children but also adults—including science teachers—have stereotypical images of scientists that exert a negative influence on teaching (Scherz and Oren 2006).

The study by Buldu (2006) analysed 42 drawings of scientists made by 30 children aged 5 to 8 years old. The results indicate that most children have a stereotypical image of scientists, i.e. they see the scientist as someone who performs research or attempts to invent a new product. Buldu considered the following as stereotypical images: (a) symbols of research: such as scientific instruments and laboratory equipment of any kind; (b) symbols of knowledge: primarily books and cabinets, technology and the products of science. Social scientists were represented, which to the children corresponded to journalists who work with a typewriter, novelists/poets, painters and professors who teach in a classroom. In Buldu's (2006) study, the children's perceptions on the role the scientist plays in society varied according to the following parameters: (a) age (the older children drew non-stereotypical and more detailed images of scientists), (b) gender (no boy drew a female scientist, although some of the girls did) and (c) socioeconomic level (the children of parents of lower socioeconomic status drew more stereotypical images, with the children of parents of higher socioeconomic status drawing different images of scientists).

Zhai et al. (2014) explore primary children's (ages 9–10) images of doing science in school and how they compare themselves with 'real' scientists. Results indicate that the images of learning science in school that most of the students held were conducting hands-on investigations, learning from the teacher and completing the workbook. In addition, students reported that scientists are more likely to work alone and do things that are dangerous. Moreover, students often viewed themselves as 'acting like a scientist' in class, especially when they were doing experiments, that they were unlike a scientist because they believed that scientists work alone with dangerous experiments.

The research's findings confirm that young children can make distinctions between school science and 'real science'; there are different types of scientists and a considerable presence of stereotypical images.

Conceptions about the Nature of Science

The study of conceptions of NOS is acknowledged as a goal in the teaching and learning of science in various international studies and curricula (AAAS 1990; Lederman et al. 2002; Lederman 1992; National Research Council [NRC] 1996; NRC 2000).

According to Lederman (2007), "NOS typically refers to the epistemology of science: science as a way of knowing, or the values and beliefs inherent to scientific knowledge and its development" (p. 833). In other words, NOS alludes to the epistemological bases of scientific activities and the characteristics of the knowledge resulting from those activities (Lederman 2007).

NOS is considered to be a part of scientific literacy in various curricula (AAAS 1990; Karakas 2011; NRC 1996, 2000), wherein it is assumed that understanding NOS will allow the public (teachers, students and society) to better understand science so that they are able to make decisions about scientific matters (Karakas 2011). With respect to the relevance of the understanding of NOS by the public, Driver et al. (1996) provide five supporting arguments: (1) to make sense of science and manage the technological objects and processes in everyday life (utilitarian), (2) for informed decision-making about socioscientific issues (democratic), (3) to appreciate the value of science as part of contemporary culture (cultural), (4) to develop an understanding of the norms of the scientific community that embody the moral commitments that are of general value to society (moral) and (5) to facilitate learning the subject of science (science learning). According to Lederman (2007), even when those arguments are essentially intuitive, have little empirical support and are difficult to be actually accomplished by the students, they are relevant for science teachers to be able to understand the various conceptions of NOS.

Some studies discuss the conceptions of NOS from a curricular perspective (AAAS 1990; Karakas 2011; NRC 1996). It is also possible to find studies that sought to characterise the views of science teachers (Cachapuz et al. 2011; Gil-Pérez et al. 2001), or of students alone (Buldu 2006; Constantinou et al. 2010; Kosminsky and Giordan 2002; Newton and Newton 1998), or even studies that provide approximations of the views of science teachers and students (Driver et al. 1996; Lederman 2007).

Lederman (2007) provided an important review of the studies of the conceptions of K-12 teachers and students of NOS:

> (a) K–12 students and K–12 teachers do not typically possess “adequate” conceptions of NOS; b) Conceptions of NOS are best learned through explicit, reflective instruction as opposed to implicitly through experiences with simply “doing” science; (c) teachers’ conceptions of NOS are not automatically and necessarily translated into classroom practice; (d) teachers do not regard NOS as an instructional outcome of equal status with that of “traditional” subject matter outcomes (p. 869).

With respect to teachers’ conceptions or views of NOS, we found some studies that discuss and characterise the epistemological aspects (Cachapuz et al. 2011; Gil-Pérez et al. 2001; Karakas 2011; Lederman 2007). However, when we sought to study children and youths’ conceptions of NOS, such views become less epistemological and closer to their daily life—their cultural, social and political reality (Akerson and Abd-El-Khalick 2005; Buldu 2006; Newton and Newton 1998).

To understand students’ views of NOS, Constantinou et al. (2010) provide evidence showing that they tend to characterise science using some specific terms, such as 'discovery' and 'experience', rather than as a field of studies that aims at achieving a better understanding of the world. Other studies suggest that students conceive of science as an attempt to improve quality of life (Constantinou et al. 2010; Driver et al. 1996; Lederman 2007). This view seems to be reinforced by the mass media (TV, newspapers, cinema, the Internet and others), which often present incomplete or incoherent scientific concepts (Kosminsky and Giordan 2002).

In an empirical study conducted with youths aged 9, 12 and 16 years old, Driver et al. (1996) identified three characteristics of representations of NOS that were related to epistemological aspects: (1) the aim of scientific work (by scientists), (2) the nature and status of scientific knowledge (including the relationship between evidence and explanation, the role of experimentation, and the nature of theories) and (3) science as a social enterprise (scientists' characteristics, the social nature of scientific communities, the relationship between scientific communities and other social groups and the influence of society).

According to Driver et al. (1996), students' views on science are also usually built and developed as taught in the classroom. It is within this scenario and through the teachers' actions or science textbooks that the activities performed (reading, experimentation, problem solving, etc.) reinforce the views that are developed (Buldu 2006; Driver et al. 1996).

Conceptions of the Nature of Technology

As described in the previous section, there is much discussion within the academic milieu about NOS and its role in science education. This debate denotes a lack of consensus about which are the coherent students' conceptions and how to develop them (Driver et al. 1996; Lederman 2007). The situation for NOT is quite similar (Constantinou et al. 2010; DiGironimo 2011; Lederman 2007).

The study by DiGironimo (2011) provided a literature review on scientific and technological literacy and the philosophy and history of technology, with the goal of developing a conceptual framework for NOT. In that study, the author detected five 'global dimensions of knowledge' that characterise NOT: (a) technology as artefacts, (b) technology as a creation process, (c) technology as a human practice, (d) the current role of technology in society and (e) history of technology. The conceptual framework devised by DiGironimo (2011) for NOT included three perspectives, namely the historical, the philosophical and the educational: 'The perspectives, although distinctly unique, offer common characteristics about technology which can be merged to develop a sophisticated and internally consistent definition of technology' (DiGironimo 2011, p. 1342).

According to Ferreira-Gauchía et al. (2012) and Gil-Pérez et al. (2005), attention is not paid to technology in science education, which is merely seen as 'applied science', i.e. as something that comes 'after' science. Gil-Pérez et al. (2005) question such a simplistic view of the relationship between science and technology, which is historically rooted in an uneven valuing of intellectual and manual labour and seeks to demonstrate how the absence of the technological dimension in science education contributes to a naïve and distorted view of science and technology, which exerts a substantial impact on the scientific and technological literacy needed by all citizens.

Investigating students' conceptions of NOT, a study by Constantinou et al. (2010) showed that students tend to vaguely interpret technology as a field somehow related to improved quality of life; students were found to restrict the scope of technology to modern technological achievements, such as computers, and to ignore older devices, such as the catapult and caravels. Students also tended to reduce technology to its final products and find it difficult to consider historical aspects of technology, such as inventiveness and creativity, in the project development process (Constantinou et al. 2010).

While assessing students' understanding of the difference between science and technology, Constantinou et al. (2010) found that youths (aged 11 to 15 years old) were unable to differentiate between the aims of science and those of technology. Those authors further found that students had a vague notion of both domains and that they tended to use a large number of different criteria to distinguish between the two in a non-systematic, inconsistent manner. The data collected by Constantinou et al. (2010) also showed that students' age and educational levels did not seem to exert a significant impact on the validity and systematic nature of their patterns of response related to the difference between science and technology. According to Acevedo et al. (2003), this difficulty in distinguishing between science and technology is caused by an overlapping of their objectives, leading to the notion of 'technoscience', which is a hot topic of discussion among some contemporary philosophers (DiGironimo 2011) .

According to some authors, children and youth's difficulty in understanding NOT is reinforced by the use of the word "technology", which is sometimes associated both with objects powered by electricity and with information and communication technologies (ICTs) (Chang and Tsai 2005; Lee et al. 2011). Pérez Gomez (2012) considered such difficulty to be related to the advent of the 'information society', that is to say, students live in an 'age of digital culture', whereas schools find it difficult to follow and share that reality.

To better understand the theoretical foundation of these three conceptions, we present in Table 1 a synthesis of the literature review, i.e. we present the main categories of conceptions of the role of scientists, nature of science and nature of technology. In this table, the different literatures come together to motivate the current research.

In Newton and Newton's (1998) study, students' image of science, technology and scientists begins to be developed early, in elementary school, and remains constant for many years, even after significant changes in the science curriculum. "Children generally form their first impressions at an early stage of their development and these impressions are most likely formed at school" (Buldu 2006, p. 124). Considering that students' conceptions begin to form in elementary school and persist for many years, how can we identify them to reduce their distortions? The next section describes the methods used in our study, which sought to identify such conceptions based on several categories and provide guidance for overcoming such conceptions.

Methods

We have sought to identify studies that investigate students' conceptions of NOS and NOT. Because our aim is to understand children and youths' conceptions of NOS and NOT in an informal science-teaching setting, we performed a qualitative study to describe and analyse the participants' responses and drawings. We used the theoretical framework described in the first section as the basis to develop an instrument for data collection and analysis. Data collection was performed using a questionnaire with open-ended (to respond by writing or drawing) and closed-ended (multiple choice and Likert scale) questions. The data were analysed using an instrument designed to understand the statements and drawings that reflect the participant's conceptions of NOS, NOT and the role of scientists in society, based on categories and indicators.

Table 1 Main categories of conceptions of the role of scientists, nature of science and nature of technology

Axis	Author	Aim	Theme	Categories
Conceptions of the role of the scientist	Buldu (2006)	To analyse the images of scientists in 42 drawings made by 30 children aged 5 to 8 years old	Children's conceptions of the image of scientists	*Type*: scientist; social scientist. *Gender*: male or female scientist. *Activity*: research; experiment; invention; observation; teaching; writing; repairing/manipulating; art; other (examining, reading, searching, etc.). *Features*: symbols of research; knowledge symbols; technology; other features (animals, plants, moon/stars).
	Newton and Newton (1998)	To determine whether children's stereotyped conceptions moved after a period of fifth grade, using the 'English and Welsh National Curriculum Order for Science'	Children's conceptions of the image of scientists	*Attributes of the figure*: sex, laboratory coat, spectacles, beard and baldness.
	Scherz and Oren (2006)	To examine the images of 100 students from 6 classes (eighth or ninth grade) related to science and technology, the workplace and the relevant professions. It also describes the effect on these images caused by an instructional initiative, 'Investigation into Science and Technology' (IST), designed to introduce students to science and technology in 'real life'.	Students' conceptions of scientific and technological professions	*Scientific profession*: scientific professions (i.e. biologists, physicists); professions using scientific knowledge (i.e. doctors, nurses); descriptions of the working environment; naming scientific disciplines; non-scientific professions (i.e. teacher, historian); did not answer. *Technological professions*: technological professions (i.e. engineers, electricians); descriptions of the working environment; non-technological professions; did not answer.
			Students' conceptions of the workplace of scientists and technologists	*Architectural depiction of the site*: external view; internal view. *Complexity level of the interior*: general view; specific view; layout of the site. *Negative aspects*: expressions of warning/hazard *No drawings.*
	Kosminsky and (Giordan 2002)	To identify youths' (15 to 18 years old) conceptions of the behaviour of scientists 3 days per week (Monday, Thursday	Student's conceptions about the daily activities	General descriptions of drawings.

Table 1 (continued)

Axis	Author	Aim	Theme	Categories
		and Sunday) at the following times of the day: 10 h , 16 h and 23 h	of scientists	
Conceptions of the nature of science	Newton and Newton (1998)	To determine whether children's stereotyped conceptions moved after a period of fifth grade, using the 'English and Welsh National Curriculum Order for Science'	Children's conceptions of the nature of science after introduction of a national curriculum	*Regarding science as a body of knowledge and the study of*: living things; materials; forces and energy; earth and space; other. *Regarding science as a process involving*: manipulative procedures; observation; measuring; recording and communicating information; thing; using information technology.
	Driver et al. (1996)	To investigate children's (of three different ages: 9, 12 and 16 years old) conceptions of the nature of science	Children's conceptions of the nature of science	*The purposes of scientific work;* *The nature and status of scientific knowledge (including the relation between evidence and explanation, the role of experimentation and the nature of theory);* *Understanding science as a social enterprise.*
	Akerson and	Abd-El-Khalick (2005)	To explore elementary students' views of (NOS) to see how well they align with national re-form recommen-dations (AAAS, 1993; NRC 1996)	Children's conceptions of the nature of science and comparison to the national curriculum
	Distinction between observation and inference. *The creative and imaginative nature of science.*			

Table 1 (continued)

Axis	Author	Aim	Theme	Categories
	The tentative yet reliable nature of science.			
	Akerson et al. (2011)	To explore elementary students' views of (NOS) (kindergarten through third grade) in a variety context (informal, suburban and urban)	Aspects related with the nature of science	*Observation* vs. *Inference* *Subjectivity and Social/Cultural Embeddedness* *Creativity and imaginative* *Empirical evidence* *Tentative*
	Teixeira et al. (2009)	To identify students' conceptions of the nature of science and their transformation by means of a contextual approach to physics education	Students' conceptions of the nature of science	*Study of the natural phenomena* *Set of organised knowledge* *Development of methods* *Confirmation of facts*
Karakas (2011)	To examine how college science faculty who teach	introductory-level undergraduate science courses, including chemistry, biology, physics and earth science, understand and define science and nature of science (NOS)	Definitions of science and conceptions of the nature of science by college science faculty	*How college science faculty define science*: it is empirical and experimental; it explains reality; it is an inquiry and asking the good questions; it is a way of knowing and understanding the world; it is explaining what you see using the scientific method; it is problem solving. *Views on the tentative nature of science.* *Views on the empirical nature of science.* *Views on the subjective nature of science*. *Views on the creative nature of science*: Affirming creativity; Creativity in designing an experiment to a research question; Depends on the individual, the best science is very creative; Data collection is not creative. *Views on the social and cultural nature of science*: Society and culture effects how and what type of science is conducted (political and social pressures; pressure of funding; scientists' upbringing and background); Science is universal, but there are some personal cultural influences; Science is everywhere in our lives (scientists are cooks and mechanics).

Table 1 (continued)

Axis	Author	Aim	Theme	Categories
				Functions of and relationships between scientific theories and laws: Hierarchical relationship; Theories become laws with sufficient time and testing; Mixed views on the relationships between scientific theories and laws; Different types of knowledge, not hierarchical. *Differences between observation and inference in science.*
Conceptions of the nature of technology	DiGironimo (2011)	Investigating student conceptions about the nature of technology	Conceptions about the Nature of Technology by students	*Technology as an artefact* *Technology as a creation process* *Technology as a human practice* *History of technology*
	Ferreira Gauchía et al. (2006)	Identify conceptions of technology conveyed in schoolbooks	Conceptions of science and technology in schoolbooks	*Instrumental approach*: set of tools, artefacts and machines *Cognitive approach*: application of knowledge (prescientific and applied science) *Systemic approach*: scientific-technological, historical-cultural, organisational-social, verbal-iconographic, technical-methodological components
	Ferreira-Gauchía et al. (2012)	Identify conceptions of technology and analyse how such conceptions influence the students' technological literacy	Distorted conceptions about the nature of technology	*Technology as application of scientific knowledge* *Technology as the main responsible for environmental problems* *Technology as solution for the main problems of humankind* *Technology as scientific development preceding science* *Technology related with negative consequences*
	Constantinou et al. (2010)	To assess students' understanding about the distinction between science and technology	Students' conceptions of technology	*Improving human health* *Constructing or improving instruments* *Addressing environmental problems* *Preserving/enhancing the quality of life* *Improving human safety* *Improving machines*

This study adopted a qualitative approach that was grounded in the studies by Silverman (2001, 2010). To facilitate the understanding of our proposal and how we intend to collect the corresponding data, we describe the study design in full detail below.

The Construction of Instruments for Data Collection

Constantinou et al. (2010) and Lederman (2007) point to an increasing need to develop effective instruments to identify and characterise students' conceptions of NOS and NOT. Thus, it is essential to develop a data-collecting tool that might help teachers and educators propose curricula and teaching methods fit to overcome alternative conceptions of NOS and NOT (Bell and Lederman 2003; Buldu 2006; Cachapuz et al. 2011; Constantinou et al. 2010; Lederman 2007; Lederman et al. 2002).

According to Constantinou et al. (2010), most of the instruments employed to assess the conceptions of NOS and NOT "have been developed largely in reliance on forced-choice instruments such as multiple-choice or Likert scale tests (e.g. TOUS, WISP, STI, NOSS, NOST, VOST, NSKS for assessing NOS and PATT for assessing NOT)" (Constantinou et al. 2010, p. 148). Other techniques to assess the conceptions of NOS and NOT are open-ended interviews, which often are decontextualised and abstract to the respondents (e.g. What is science? What is technology?) (Constantinou et al. 2010).

The literature also describes instruments such as interview protocols that combine contextualised and decontextualised items (e.g. items concerning socioscientific issues, or SSI) (Scherz and Oren 2006). An alternative approach combines written answers and open-ended questions with follow-up interviews in which the participants are invited to further explain their responses (Constantinou et al. 2010; Lederman 2007). To accomplish the aims of this study, we followed Constantinou et al.'s (2010) guidelines and prepared two instruments for data collection: a questionnaire and an interview.

Questionnaire The questionnaire included five questions of different types, i.e. three open-ended questions, one multiple-choice question and one question to be answered on a Likert scale. The questionnaire included a text that explained the nature and relevance of the study and ensured that the respondents' identities were protected. The questionnaire was designed to identify some categories along two axes of analysis. The first axis was 'Understanding of the nature and teaching of science': this axis consisted of two questions designed to identify the participants' (a) conceptions about the nature of science (one open-ended question) and (b) conceptions about the role of the scientist (one open-ended question). The second axis was 'Conceptions about the nature of technology and use of computers': this axis consisted of three questions to investigate the participants' (a) conceptions of technology (one open-ended question), (b) the main digital technologies to which they had access (one multiple-choice question) and (c) the actions related with the use of Internet-connected computers (one Likert-scale question). The participants were free to respond to the open-ended questions by either writing or drawing.

The first version of the questionnaire was shown to three Brazilian university professors specialising in science education and the use of ICT to assess whether the questions were understandable and appropriate for the study's purpose.

After the changes suggested by the aforementioned professors were made, we conducted two pilot studies. We searched for a school with characteristics similar to the setting in which final data collection would be performed. One pilot study was performed at a municipal school in Ilhéus, State of Bahia, Brazil. Twenty students attending sixth grade in 2012 volunteered to participate in the pilot study. The questions for which the responses did not provide the desired information and the questions that the participants had difficulty to understand were reformulated or eliminated. After those changes were made, we invited a state school in Itabuna Municipality, Bahia, Brazil, to participate in the second pilot study. The sample was composed of eight volunteers attending sixth grade and eight volunteers attending seventh grade because the final study population would be composed of students from different grades attending different school years. We analysed the results and thus reached the final configuration of the questionnaire to be used for data collection (see Appendix A).

The data collected in the pilot studies were used both to validate the questionnaire to be used for data collection in our study and to validate the instrument for analysis of the participants' conceptions of NOS, NOT and the role of the scientist.

Semistructured Interviews with the Students Who Participated in Data Collection A protocol for semistructured interviews was developed to complement and dispel doubts about the data collected with the questionnaire. In other words, we wanted to investigate more thoroughly the participants' conceptions of science and technology and their relationship with science teaching, as identified in their responses to the questionnaire (see Appendix B).

Data Collection: Setting and Subjects

Contextualisation of the Setting

Our study is also a *case study* (Yin 2003) because we seek to understand the behaviour of a group of children and youths in an informal science-teaching setting "considered as a single entity, different from any other, within a given specific contextual situation, which is their natural environment" (Sousa 2009, p. 138).

The participants' natural environment, or our study setting, is represented by a programme for social inclusion, education and technology named Project 'Setting, Challenges and Opportunities (Espaço, Desafios e Oportunidades—EDO)', developed in the Tapada das Mercês area, Sintra municipality, Portugal. Project EDO tends to attract students from various schools in the area, some attending elementary school but most attending lower secondary school. Project EDO is supported and funded by the government's 'Programme Choices [Programa Escolhas]',[2] which also provides support to other projects across Portugal.

Project EDO was started in 2004 in a socially vulnerable area characterised by social and economic adversity, with a predominance of families primarily composed of immigrants. To provide support to students in that context, the project develops 'school inclusion', 'non-formal education' and 'digital inclusion' activities all year round at a computer-equipped facility; in addition, it conducts several workshops.

Supported through an interdisciplinary approach, Project EDO develops practical activities that are related to the students' reality outside of school hours. It features activities such as thematic workshops based on developing projects within a science and technology education

[2] 'Programme Choices' is funded by the Institute of Social Security, the General Secretary of Education of Portugal and the European Social Fund, through the Human Capital Operational Programme/National Strategic Reference Framework or HCOP/NSRF. This programme funds social inclusion projects for vulnerable communities, many of which are in areas with high concentrations of immigrant descendants and ethnic minority groups across Portugal (Available at: http://www.programaescolhas.pt/).

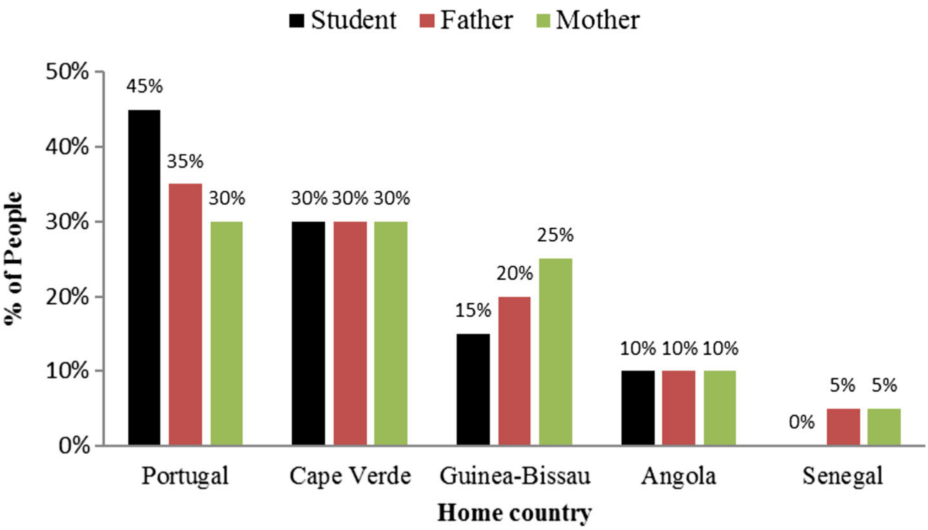
context. The main workshops are devoted to aircraft modelling, in which students design aircraft and rocket models (themes related to the space, universe, aeronautics and astronomy etc.), along with activities involving robotics (themes related to alternative energy), in which students design models of ships and cars powered by sunlight and wind turbines. Those activities, which are conducted in a non-formal setting, aim to complement the local schools' formal education in science and technology and are more practical than theoretical because theory is already taught in the classroom. Project EDO is intended to develop project-based activities aiming to achieve social and digital inclusion. All of the activities are multidisciplinary and interdisciplinary, so the students can make sense of and apply them in practice.

Project EDO is supported by the Centre for Digital Inclusion, which is composed of a computerised facility named CID@NET, founded in 2006, to promote the digital inclusion of the participating students.

Contextualisation of the Participants

Our sample, 'considered as a single entity' (Sousa 2009), was composed of children and youths enrolled in Project EDO who were invited to participate in this study for 1 week at the beginning of the school holidays in 2013. The participants returned a parent-signed consent form to the Project EDO coordinators, in which the parents agreed to their children's participation in the video-recorded interviews. The questionnaire was answered by 20 youths (70% male and 30% female), divided into the following age groups: 10 years old (20.0%), 11 to 12 years old (55.0%), 13 to 14 years old (20.0%) and 15 years old (5.0%). Most attended sixth grade (55.0%), whereas others attended fourth grade (5.0%) and fifth grade (40.0%). Nine participants were Portuguese nationals (45%) and the remainder of the sample came from four African countries: Cape Verde, Guinea-Bissau, Angola and Senegal. All of them lived in a residential area with families from various nationalities, under vulnerable socioeconomic conditions and with high school failure rates. Plot 1 depicts the home country of the participants and their parents.

All of the participants spoke Portuguese and some of them also spoke African dialects as a result of the ethnic subgroups to which they belong.



Plot 1 Home country of the participating students and their parents

During this study, we had the support of Project EDO staff, which was composed of the project coordinator (a teacher specialising in science and technology), one psychologist, one computer technician and one intern.

To achieve a more thorough understanding of the participants' conceptions of NOS and NOT, they were also invited to participate in a semistructured interview. Five of them agreed and the interviews were video-recorded and transcribed. Participants were identified as A1 to A5 protect their identity.

Construction of the Instrument for Data Analysis

Considering the issues discussed regarding the study's theoretical framework and the participants, we elaborate an instrument to analyse the participants' responses based on concrete categories and that met both the study aims and Lederman's (2007) requirements.

For that purpose, the various studies of the conceptions of NOT and NOS provided us a set of indicators that guided the development of the instrument to analyse the data extracted from the questionnaires answered by the study participants. The instrument we will use to analyse the participants' conceptions will not emerge from the responses given in the questionnaire and interviews, but instead will be created to interpret those conceptions.

First, we gathered the various conceptions in different contexts and with different subjects, to map their predominance in different scenarios (the role of the scientist, NOS and NOT). Those conceptions were derived from different studies (Akerson et al. 2011; V. L. Akerson and Abd-El-Khalick 2005; Buldu 2006; Constantinou et al. 2010; DiGironimo 2011; Ferreira Gauchía et al. 2006; Ferreira-Gauchía et al. 2012; Gil-Pérez et al. 2001; Karakas 2011; Kosminsky and Giordan 2002; Liou 2015; Newton and Newton 1998; Scherz and Oren 2006; Teixeira et al. 2009).

The main reference for the preparation of Table 2 was the studies by Driver et al. (1996) and Lederman (2007) (Bell and Lederman 2003; Lederman 1992; Lederman et al. 2002) that feature different works on the conception of the role of the scientist, NOS and NOT. For completeness, the studies by Driver et al. (1996) and Lederman (2007) and other important authors working on this theme were also used (Abd-El-Khalick et al. 2001; V. L. Akerson and Abd-El-Khalick 2005; Buldu 2006; Gil-Pérez et al. 2005).

Based on a reorganisation of the conceptions listed in Table 1, we synthesised them into three dimensions of analysis in our instrument for data analysis as shown in Table 2: (1) conceptions of the role of the scientist, (2) conceptions of the nature of science and (3) conceptions of the nature of technology. Those three dimensions consist of several categories that encompass the various conceptions and are defined based on our aim to determine what children and youths think about NOS, NOT and the role of the scientist.

To validate the instrument, we analysed the responses of the questionnaire applied in the pilot study (Appendix A), and we identified the conceptions. The conceptions identified that were not included initially in the system of categories described in Table 2 were added to the final version of the instrument. To facilitate an understanding of the system described in Table 2, we discuss each dimension of analysis in full detail below.

Conceptions About the Role of the Scientist

The first dimension of analysis consists of six categories, which include the following indicators: (1) type, (2) gender, (3) characteristics, (4) activity, (5) symbols and (6) work setting (Table 3).

Table 2 Synthesis of the categories used to analyse the main conceptions

Dimensions of analysis	Categories
Conceptions of the role of the scientist	Type Gender Activity Characteristics Symbols Work setting
Conceptions of the nature of science	Empirical conception Epistemological conceptions Social and cultural conception Creative and imaginative conception of science Technical and instrumental conception
Conceptions of the nature of technology	Instrumental conception Cognitive conception Systemic conception Value-based conception

The category 'type' was defined based on studies by Buldu (2006) and Scherz and Oren (2006). The category 'characteristics' initially followed the recommendations by Kosminsky and Giordan (2002) and Newton and Newton (1998) and thus included the scientist's 'extrinsic characteristics' only, i.e. external characteristics that were mainly present in drawings. Analysis of the responses given in the pilot study allowed us to identify additional categories. We found that some intrinsic characteristics were mentioned in the texts written by the participants in the pilot study, such as "A scientist is a very intelligent person!" (Pilot—A02, 12 years old) or "All scientists are mad!" (Pilot—A13 – 10 years old).

With respect to the category 'activity', we followed the suggestions by Buldu (2006), but additional verbs characterising scientists' activities of scientists were included after the pilot study; for instance, to discover, to know, to explore, to study, to construct, to question, etc.

With respect to the category 'symbols', we looked for support in Buldu's (2006) study, but following the instrument validation we added 'symbols indicating danger' because drawings of explosions and skulls stood out in our pilot study. Finally, the last category, 'work setting', corresponds to the indicators formulated by Scherz and Oren (2006). However, after the validation study, we felt that we needed to add further indicators of the work settings of scientists: planet, science museum, factory and classroom. Those settings make sense because we considered both social and technological scientists as the subjects of the students' conceptions.

Conceptions about the Nature of Science

The second dimension of analysis, NOS, is composed of five categories: (1) empirical conceptions of science, (2) epistemological conceptions of science, (3) social and cultural conceptions of science, (4) creative and imaginative conception of science and (5) technical and instrumental conceptions of science.

According to Lederman (2007), "scientific knowledge is tentative (subject to change), empirically based (based on and/or derived from observations of the natural world) and subjective (involves personal background, biases, and/or is theory-laden); necessarily involves human inference, imagination and creativity (involves the invention of explanations) and is socially and culturally embedded" (p. 834). Our object of analysis, which is based on different

Table 3 Categories and indicators regarding conceptions of the role of the scientist

Categories	Indicators	Description	Examples
Type	(a) *Scientist*: physicists, chemists, biologists, doctors, astronauts, etc.; (b) *Social scientist*: professor, journalist, historian, etc.; (c) *Technological scientist*: laboratory technicians, engineers, etc.	Characterises the main types of scientists	A scientist is someone who *goes to the moon* and *forecasts the weather.*
Gender	(a) Male; (b) Female	Characterises the scientist's gender	I see a scientist as *a man* who discovers several things.
Characteristics	(*a*) *Extrinsic*: coat; glasses; beard; baldness; hair up; long hair, with clothes, alone/with company, etc. (*b*) *Intrinsic*: mad, intelligent, etc.	Identifies the physical characteristics and personality traits of a scientist	People say all scientists are *mad*.
Activity	To investigate/research, discover, know, explore, study, experiment, invent, observe, teach, write, repair/fix, construct, question, communicate information—explain, think, use information technology, make art, examine, read; predict, etc.	Identifies action verbs to characterise the scientists' activities	The scientist *predicts* when it will rain.
Symbols	(*a*) *Symbols of research*: products of science, laboratory materials and equipment (microscope, test tubes, etc.) (*b*) *Symbols of knowledge*: equations, computers, books, bookshelves, cabinets, writing-boards, pencils, etc. (*c*) *Symbols of danger*: explosions, prohibitions, etc.	Identifies the main symbols that characterise the practice of a scientist	The scientist wears a *mask* to perform experiments.
Work setting	(a) *No setting* (b) *External setting* (nature, planet, space, etc.) (c) *Internal setting* (laboratory, science museum, factory, classroom)	Identifies the scientist's work setting	The scientist looks at planet Earth *from space*.

conceptions and Lederman's (2007) study, includes elements that characterise NOS as having an empirical, moral and ethical basis; being creative and imaginative; being influenced by culture and society; being related to technology and having direct implications for the epistemology of science.

Table 4 describes the aforementioned categories and some examples identified in the analysis of the pilot questionnaire.

The first three categories in Table 4 are reported in the studies by Akerson et al. (2011), Akerson and Abd-El-Khalick (2005), Karakas (2011), Newton and Newton (1998) and Teixeira et al. (2009) (see Table 1). The 'creative and imaginative conception' of science is found in the studies by Akerson et al. (2011), Akerson and Abd-El-Khalick (2005), Lederman (2007) and Newton and Newton (1998). The 'technical and instrumental conception' appeared repeatedly in our pilot study, which alerted us of the need to include it in our system of analysis. For example, "Science is an *advanced technology*" (Pilot—A3—11 years old) and "To me, science helps in *developing* and *knowing* about *technology*" (Pilot—A2—11 years old).

Table 4 Categories to identify conceptions of the nature of science

Categories	Description	Examples
Empirical conception	Characterised by development of methods; confirmation of facts, description of laws, theories and discovery of something	Science is a way of *discovering* the world! Science is doing *experiments*
Epistemological conceptions	Characterised as a body of knowledge (scientific content, teaching subjects, etc.); study of …; understanding reality, learning, etc.	It is the *study of nature*! It is a very important *subject*!
Social and cultural conception	Characterised as non-neutral; influenced by political, economic, social and ethical factors; it improves the quality of life of people; there is a relationship between science and society.	It is a way of *changing the world* into something better! Something that *cures diseases*.
Creative and imaginative conception of science	Characterised by human imagination and creativity in the development of functional theoretical models rather than as true copies of reality	Science is to know what is *inside the black hole*!
Technical and instrumental conception	Relates science to technological devices	To me, science helps to develop and know *technology* better. It is to *use the telescope* to discover new planets.

Conceptions of the Nature of Technology

The last dimension of analysis concerns conceptions of the nature of technology (Table 5) and is composed of four categories: (1) instrumental conception, (2) cognitive conception, (3) systemic conception and (4) value-based conception.

The first three categories are mentioned in the study by Ferreira Gauchía et al. (2006), and the category 'systemic conception' corresponds to the 'technology components' in Acevedo et al. (2003). Table 6 presents a summary of those components, which guided our analytical instrument (Table 2).

To understand technology as a complex system is not only to attempt to overcome distorted conceptions of NOT but also to insert it within a social, political, economic and cultural context, thus detaching it from its neutral character.

We also emphasise the category 'value-based conception', which appeared following the validation of our analytical instrument. This category represents the students' opinions on the role technology plays in their lives, for instance, technology: "It's *something good*" (Pilot—A13—11 years old) and "To me, technology is *something very important*" (Pilot—A04—12 years old).

Based on the categories described in Tables 3, 4 and 5 and the three research dimensions, we will analyse the data that were collected with the questionnaire and were complemented by the interviews to achieve the aims of this study. The classification system adopted herein was developed within the context of the conceptions of NOS and NOT of children and youths. However, it might also be used to identify the conceptions of other individuals in their social contexts. In summary, the aim of the categories described above is to broaden the understanding of the conceptions beyond those indicated by the participants and the literature because the participants' responses are characterised by a specific social and cultural context.

Table 5 Categories to identify conceptions of the nature of technology

Categories	Definition	Examples
Instrumental conception	Characterised by collections of tools, artefacts and machines	It's the *computer*. The *cell phone* is a technology.
Cognitive conception	Characterised as the result of the application of theoretical knowledge	Technology is a way for people to *learn* more about things.
Systemic conception	Characterised as a complex and structured system of components: instruments, skills, production and control processes, organisational issues, legal resources, natural resources, scientific aspects, social repercussions, the environment, etc.	Technology means *science* (*scientific-technological*). *Advancements* in many things because in the past people had to cook on wood-burning stoves, but now they have automatic stoves (*historical-cultural*). To me, technology is a way of *discovering* the world! (*technical-methodological*)
Value-based conception	Characterised by opinions based on personal points of view and/or value judgments of science	It's *something good*!

Results and Discussion

Based on the responses to the questionnaire and in the interviews, the results were distributed across three groups: (1) conceptions of the role of the scientist, (2) conceptions of the nature of science and (3) conceptions of the nature of technology.

Conceptions about the Role of the Scientist

To understand the participants' conceptions of the role of the scientist, we analysed their responses to the questionnaire, which included three written texts, nine drawings and eight

Table 6 Components that characterise the systemic conception of the nature of technology

Components	Definition
Scientific-technological component	Stresses the mutual relationship between science and technology while respecting their singular purposes and aims; technology makes use of scientific knowledge, which is reworked and adjusted in the technological context through the use of some methodological procedures similar to the ones used by science. Also, science receives numerous contributions from technology: not only instruments and systems but also methods, theoretical knowledge, concepts and models that are used as analogies and metaphors, etc.
Historical-cultural component	Characterised by the relationship among the techniques developed by humankind and the changes that they cause in the environment, culture and people's living conditions; this component includes arts such architecture, painting, sculpture, music, photography, cinema, etc.
Organisational-social component	Highlights technology as a factor with decisive influence on the various modalities of social organisation
Verbal-iconographic component	Stresses modes of expression and communication proper to technology: symbols, diagrams, specific vocabulary, etc.
Technical-methodological component	The set of the technical skills and abilities needed to work with instruments and manufacture products and other technological systems; also, the procedures and strategies required to solve actual problems in concrete situations

Source: Acevedo et al. (2003)

drawings accompanied by text. In the latter case, the written text had variable functions, in addition to the fact that the drawing strokes exhibited different levels of complexity.

Upon applying the system of analysis described in Table 3, we found that the responses that contained more information were the ones with more written text and drawings. We first present our analysis of the written texts, then our analysis of the drawings and finally our analysis of the drawings accompanied by text to analyse the conceptions of the role of the scientist.

Analysis of Texts The written texts were short and had few sentences (Table 7). Considering our system of categories, the participants did not specify the scientists' gender, extrinsic characteristics, symbols and work setting in their texts. Those categories were more evident in the drawings and drawings accompanied by text.

In this first group of responses, the scientists were identified as individuals who learn, teach and experiment. We could not locate in the participants' texts a closer relationship with society and the environment. In the texts, the participants presented a stereotypical image of the scientist (intelligent, technical-experimental) and we did not detect any age-related difference in their perceptions. In Buldu's (2006) study, 8-year-old children produced less stereotypical images of scientists than did younger children. According to that author, this finding might be attributed to the children's intellectual levels and educational experience.

In addition, we found that one student characterised 'his science teacher' as a social scientist because she teaches science. Here, there are two characteristics worthy of mention: first, the fact that the 'science teacher' is a female scientist and second, the fact that no role was attributed to women in settings other than the classroom. In Buldu's (2006) study, gender-related comparisons did not detect significant differences between boys and girls. None of the boys characterised the scientist as female, whereas 5 girls out of the 20 children did. The characterisation made by the aforementioned participant in our study of his science teacher seems to reflect the underrepresentation of women in science careers (Buldu 2006).

Analysis of Drawings Nine drawings not accompanied by explanatory or descriptive text were analysed. In most cases, the scientist was male (08) (except for one student who associated the role of the scientist with his female science teacher), alone (09) (without other scientists) and not placed within a social context (05); in the cases in which a setting was attributed, that setting was a laboratory (03). These were also the characteristics identified in the study by Kosminsky and Giordan (2002), in which the scientist described by the

Table 7 Categories and indicators in the written texts on 'conceptions of the role of the scientist'

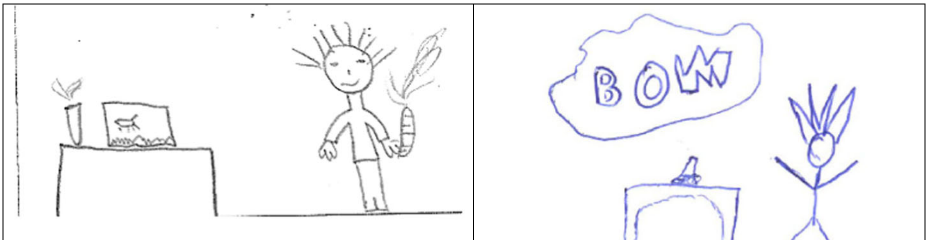
Student	Responses	Categories and indicators
A03	An *intelligent* person, always ready to *learn* new things (A03–11 years old, fifth grade).	*Intrinsic characteristics*: intelligent *Activity*: to learn
A14	She, my *science teacher*, who *teaches* everything in the *science classes* A14—11 years old, sixth grade).	*Type*: social scientist *Gender*: female *Activity*: to teach *Work setting*: internal (classroom)
A20	The image I have of *a* scientist is that he can do *experiments* (A20—10 years old, fifth grade).	*Gender*: male *Activity*: to experiment

Table 8 Categories and indicators in the drawings representing conceptions of the role of the scientist

Categories	Indicators		*N*
Type (T)	Scientist		08
	Social scientist		01
	Technological scientist		00
Gender (G)	Male		08
	Female		01
Characteristics	Extrinsic (EC)	Alone	09
		With clothes	04
		Without clothes	03
		Glasses	03
		Hair up	06
		Long hair	01
		Bald	01
		ID badge	01
	Intrinsic (IC)	–	00
Activities (A)	To explore		01
	To observe		01
	To experiment		02
Symbols (S)	Symbols of research		01
	Symbols of danger		01
Work setting (WS)	No setting		05
	Internal setting	Laboratory	03
		Classroom	01
	External setting	Space/universe	02

participants performs experiments in a laboratory "without seemingly taking the exchange of information among peers, theoretical elaborations and the experimental sciences themselves into consideration" (Kosminsky and Giordan 2002, p. 15). The drawings made by the participants in our study are characterised in Table 8.

Some of the indicators listed in Table 8 were not included in the analysis of the drawings, namely the technological scientist, the intrinsic characteristics and some of the extrinsic characteristics. With respect to the analysis of the drawings, it is worth noting that the participants' conceptions of the 'activities' performed by scientists were mere exploration, observation and experimentation, which were not attributed to any setting other than the laboratory (or the classroom). Those are stereotypical views of scientific activity, which according to Buldu (2006) might influence the students' attitudes towards science. The image of a scientist alone in a laboratory, with hair up and performing some chemical experiment remains present in many children's imagination (Fig. 1).



(A16, 11 years old, fifth-grade)

(A12, 10 years old, fifth-grade)

Fig. 1 Drawings representing stereotypical conceptions of scientists

Some authors (Buldu 2006; Newton and Newton 1998; Scherz and Oren 2006) attribute the origin of such stereotypical conceptions to the mass media (TV and Internet) or science textbooks (this item is discussed more thoroughly in the section on 'characterisation of science teaching'). Changing children's perceptions of science and scientists is a task for teachers and schools. Although it might be difficult to contradict the image of the scientist portrayed in the mass media, schools do have an influence on children's views of science, technology and scientists (Buldu 2006; Driver et al. 1996).

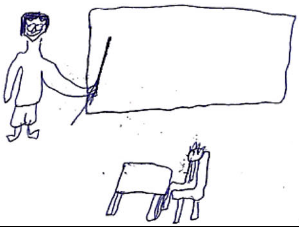
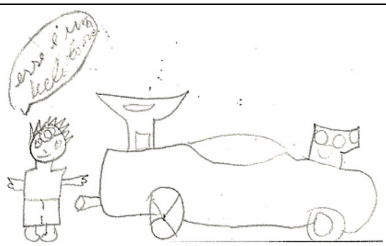
Analysis of Drawings Accompanied with Text In this case, the descriptions of the participants' conceptions of scientists offered much more detail. Table 9 describes the corresponding categories and indicators together with the frequency of mention. Among the drawings accompanied by text, we found three types of scientists (Table 9): scientist, social scientist and technological scientist. From the drawings and texts, the scientist is usually alone in his workplace, wears glasses, has the hair up (and/or normal) and is either intelligent, concerned or mad (stereotypical image).

The main activities represented were as follows: to explain, to teach, to discover, to invent and to know. In 04 drawings, the work setting was not characterised; in the cases in which it was characterised, the scientist was in a science museum, classroom (social scientist), space/

Table 9 Categories and indicators of texts and drawings of conceptions of the role of scientists

Categories	Indicators		Number
Type (T)	Scientist		04
	Social scientist		02
	Technological scientist		02
Gender (G)	Male		04
	Female		01
Characteristics	Extrinsic (EC)	Alone	05
		With company	01
		With clothes	04
		Without clothes	00
		Glasses	03
		Hair up	03
		Hair down	03
		Bald	00
		ID badge	01
		Coat	01
	Intrinsic (IC)	Intelligent	02
		Concerned	01
		Mad	01
Activities (A)	To explain		02
	To teach		01
	To discover		02
	To invent		02
	To know		01
Symbols (S)	Symbols of research		01
	Symbols of knowledge		01
Work setting (WS)	No setting		04
	Internal setting	Laboratory	00
		Science museum	01
		Classroom	01
	External setting	Space/universe	01
		Street	01

Table 10 Examples of the major categories of scientists

Types of scientists	**Drawings**	**Categories/indicators**
Social scientist	"My <u>teacher</u>" (A7, 11 years old, fifth-grade). 	G: female EC: hair down, with clothes, with company IC: - A: to teach, to explain S: symbol of knowledge (blackboard) WS: internal setting (classroom)
Technological scientist	"The scientist <u>invents</u> things" (A11, 11 years old, sixth-grade).	G: male EC: hair up, alone, with clothes CI: - A: to invent S: -
		WS: external setting
Scientist and social scientist	 "A scientist is a person <u>concerned</u> in <u>knowing</u> how the daily life of a being is and <u>knowing</u> everything that exists in planet Earth <u>inventing</u> machines and other things that might help <u>him</u>" (A18, 12 years old, sixth-grade)	G: male EC: hair down, glasses, coat, tie, alone. IC: concerned A: to know, to invent S: - WS: no setting

the universe or even on the street (technological scientist) (Table 10). In this regard, Gil-Pérez et al. (2001) observe that to overcome such distorted views of scientific work, constant dialogue is needed between students and teachers to clarify that "the work of each scientist is guided by the established lines of research and the work of the team to which they belong, whereas the idea of entirely autonomous research makes no sense" (p. 137).

The presence of some symbols in the drawings is interesting; for instance, symbols of knowledge were represented by a 'blackboard', 'vials and tubes on laboratory benches' corresponded to symbols of research and the 'explosions of chemical reactions' corresponded to symbols of danger. The absence of scientific work settings seems to indicate that the children considered themselves to be removed from the work site, which would mean that they do not feel directly involved in the scientific process, but instead that it is something restricted to geniuses/extraordinary people (drawings of scientists alone in a laboratory or 'the scientist *invents* things'). It is only in the first drawing, from Table 10, that the child is seen in the context of academic scientific work: 'My teacher' (A7, 11 years old, fifth grade).

Finally, we also found representations of the scientist that are closer to social reality: a scientist who teaches (teacher) or who is concerned about society (Table 10). Similar findings were reported by Buldu (2006), in whose study 35% of the figures in the drawings corresponded to the social scientist type. For instance, the children who participated in that study qualified journalists who work using a typewriter, novelists/poets, painters and university professors who teach in classrooms as scientists, and who therefore were different from the stereotypical images of science drawn by the participants in previous studies.

Conceptions of the Nature of Science

In the course of the literature review that we performed for this study, we were able to establish that NOS has been defined in many different ways (Abd-El-Khalick et al. 2001; Akerson et al. 2011; Bell and Lederman 2003; Lederman 2007). Despite the various studies that seek to characterise science, there is not one single definition or characterisation of NOS (Karakas 2011), and the philosophical, social and educational debate on NOS will never end (Gil-Pérez et al. 2001; Karakas 2011).

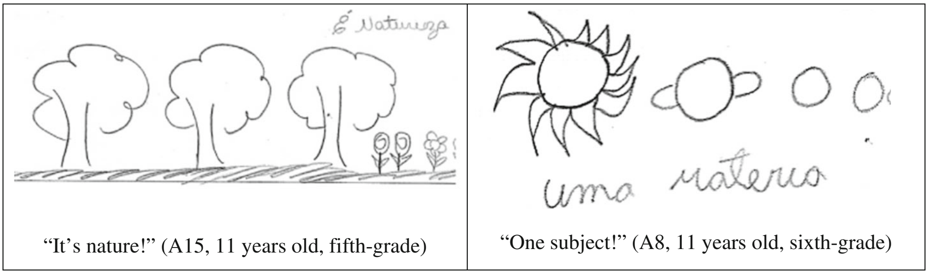
The discussions of the conceptions of NOS evidenced both in the analytical process and in the categories the children and youths' conceptions of NOS described in Table 4. The epistemological, empirical and technical conceptions were cited considerably more than the social-cultural and creative conceptions.

Epistemological Conception of Science

Eleven responses corresponded to this category, three of which were presented as written texts and eight as drawings. We included in this category responses related to cognitive and pedagogical issues, namely the study of nature and its relationships (eight), the construction of knowledge (two) and the curricular content (one). In the following examples, the epistemological conception of science is characterised by the use of expressions such as 'a way to look at the world', 'to learn', 'study of nature' and 'study of life':

> To me, science is a new way to look at the world, and I might learn much through science (A1, 12 years old, sixth grade).
> It's nature (A9, 12 years old, sixth grade).
> To me, science is the study of life, of both organic and inorganic beings (A18, 12 years old, sixth grade).

That view is close to that of Praia et al. (2002) in their description of the 'new objectives of science teaching' to overcome distorted or stereotypical views on science: (1) learning of science: such as the acquisition and development of theoretical knowledge by means of scientific content (participants A18 and A1's statements); (2) learning the nature of science: i.e. development of the nature and methods of science to become aware of the complex interactions between science and society (participants' A9 statement) and (3) practice of science: or the development of technical and ethical knowledge, among other types of knowledge related to scientific research and problem solving (participant A1's statement).



"It's nature!" (A15, 11 years old, fifth-grade)

"One subject!" (A8, 11 years old, sixth-grade)

Fig. 2 Drawings representing the epistemological conception of NOS

Some drawings characterised science as the 'study of nature' or merely related science to some 'topic learnt in science classes'. Figure 2 illustrates those types of conceptions by means of the participants' characterisation of the study of 'astronomy', 'plants' and 'animals'.

The children's drawings included aspects of their recent work in science classes, such as the study of astronomy or the 'environment' (Fig. 2). Conceptions developed based on TV programmes, science textbooks and the teachers' own conceptions reinforce the popular views on science and the scientist. According to Teixeira et al. (2009), for the conceptions of NOS to agree with the contemporary trends in the field of epistemology, science classes should incorporate a historically and philosophically contextualised approach to scientific subjects and work to understand some aspects of the scientific content, to understand the scientific approach used in the research process and to understand science as a social enterprise (Driver et al. 1996; Teixeira et al. 2009)

Empirical Conception of Science

Although this category has a direct relationship with the previous one, we chose to characterise it alone because its components include elements related to the development of methods; the demonstration of facts and the description of laws, theories and discoveries. Gil-Pérez et al. (2001) have observed that this category represents the most investigated and criticised distortion in the literature, which started in the 1960s and accompanied attempts to rehabilitate science from an atheoretical perspective centred on the so-called scientific method while ignoring scientific content and its relationship to society.

Five of the responses to the questionnaire correspond to empirical conceptions of science, being represented by terms such as to discover, to explore, to look for, to experiment, etc.

> To me, science is to discover things, to look for different beings and do new things (A12, 12 years old, sixth grade).
> It's to explore things and animals further (A4, 11 years old, fifth grade).
> To me, science is discovering and making experiments (A4, 11 years old, fifth grade).
> To me, science is to discover things about the environment, ourselves and the evolution of people and animals (A19, 12 years old, sixth grade).
> Science to me is to make science, is to discover (A20, 10 years old, fifth grade).

In those statements, we detect a conception originated in the positivist paradigm, which is grounded on Aristotelian empiricism and thus the emphasis on observation and experimentation as sources of knowledge. Analysis of the participants' responses shows that to them, NOS is directly related to 'exploration', 'conducting experiments' and 'discovery'. These conceptions exemplify the fact that the scientific method follows a particular sequence of steps that begins with data collection, followed by observation, experimentation, data analysis and formulation of laws and theories. As we mentioned above, this conception was also present in the analysis of the 'role of the scientist'.

In the participants' responses, there is an approximation of NOS with the scientific process, i.e. with the 'activities related to the collection and interpretation of data, and the derivation of conclusions' (AAAS 1990; Karakas 2011; NRC 1996). For example, scientific processes involve making observations, perform experiments and making discoveries.

Several studies have noted the discrepancies between modern epistemological views of science and children's, youths' and science teachers' conceptions of science, which are both widespread and marked by radical empiricism (Driver et al. 1996; Lederman 2007; Karakas 2011). It is worth noting that this notion, which limits scientific activity to experimentation, agrees with the notion of scientific discovery that is conveyed, e.g. in comics, movies and on television in general (Buldu 2006; Karakas 2011; Lederman et al. 2002; Newton and Newton 1998). In other words, it seems that students' views of the role of experimentation does not differ much from that which we have alluded to as the 'naïve' image of science that is widely disseminated and accepted by society (Ferreira-Gauchía et al. 2012; Gil-Pérez et al. 2001).

Technical and Instrumental Conception of Science

Three of the responses given by the participants related NOS to technological devices (two written texts and one drawing). In addition, the identification of science with technical instruments and devices is a conception that deserves more thorough analysis. In this study, this conception was represented by drawings of and terms such as computer, technology, machine, etc.

> To me, science is to teach people how to use the computer (A3, 11 years old, fifth grade).
> To me, science helps in the development of technology and in getting to know it properly (A10, 11 years old, fifth grade).

One of the students related science directly with the computer. This represents the instrumental perspective of science, which is potentiated by the increasing inclusion of technical devices in the daily life of youths and of ICT in science teaching (Beauchamp 2011; Park et al. 2009). According to the other student, technology is subordinated, or might even be reduced to science. This idea is based on the view of technology as 'applied science'. According to Constantinou et al. (2010, p. 145), "a common perspective on the relationship between the two conceives of "technology as applied science" (TAS). This view implies a unidirectional relation, according to which developments in science provide the basis for the invention of new technologies". The idea of technology as applied science has been widely discussed within the context of science education and according to Ferreira-Gauchía et al. (2012), this discussion represents a distorted but very current view. We discuss more thoroughly the technical conception of science in the section on 'conceptions about the nature of technology'.

Finally, one participant related science to a technological device: 'a telescope' (Fig. 3).

Figure 3 suggests a conception that telescope (technology) contributes to scientific development. The history of science provides countless examples showing that technological inventions might contribute to scientific progress. One such example concerns the device designed and used by Galileo and how the development of the telescope by craftsmen, which long predates our

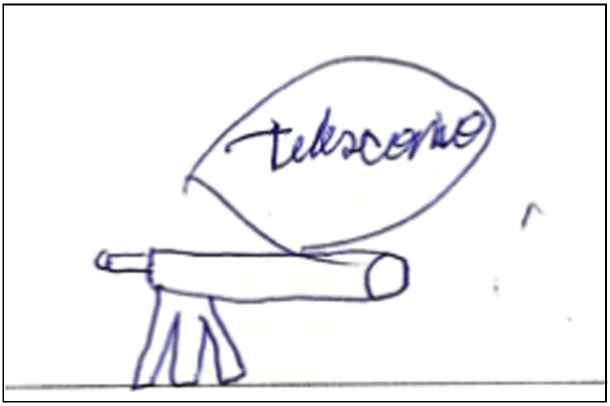


Fig. 3 Drawing of a telescope (A12, 10 years old, fifth grade)

understanding of optical phenomena, enabled scientists to perform more detailed observations and achieve a better understanding of the solar system (Constantinou et al. 2010).

Social and Cultural Conception of Science

Based on our system of categories, we can establish that one single participant expressed the social and cultural conception of science, which to Gil-Pérez et al. (2001) means 'to understand the social character of scientific development', i.e. that science is something that changes the world. This observation by Gil-Pérez et al. (2001) is represented in the response given by participant A6:

> A way of changing the world [into something] better and to get to know new things and the things in nature (A6, 10 years old, fifth grade).

The view of science manifested by that participant seems somewhat romanticised because we already know that scientific work is influenced by the problems and circumstances of various historical periods (Akerson et al. 2011; Gil-Pérez et al. 2001; Karakas 2011). Similarly, the actions of scientists patently influence the political, economic and social aspects of the corresponding contexts. Thus, one cannot say that science has no context or that it is socially neutral and that the development of science cannot be characterised as an individualistic and elitist enterprise that is implicitly based on the empiricist idea of 'discovery' which contributes to a decontextualised and socially neutral understanding of scientific activity as something performed by lone male scientists (Buldu 2006; Gil-Pérez et al. 2001; Karakas 2011; Newton and Newton 1998; Scherz and Oren 2006). We think that, as mentioned in other studies like Karakas (2011) and Lederman et al. (2007), to develop a conception of NOS in present-day science education means to look for the *socio-constructivist* aspects that lend support to the social and cultural aspects of science.

Creative and Imaginative Conception of Science

Although we searched for representations of the creative and imaginative conception of NOS during our analysis of the participants' responses, no statement in this regard could be located. For a possible explanation for this, we agree with Akerson and Abd-El-Khalick (2005) who locate the problem in students who do not understand the meaning of the concepts of 'imagination' or 'creativity'. Those authors observe that most students produce inaccurate definitions of 'scientific imagination' and creativity, whereas many do not believe that scientists might be imaginative and creative in their work. As a result, the participants in their study only achieved a better understanding of the definition of scientific 'imagination and creativity after finding that scientists do use those traits in their work. Our assumption is that this could occur in the future with the participants of this research.

Conceptions about the Nature of Technology

As Table 1 shows, NOT can be addressed from many perspectives, namely those of machines and devices, human practises and quality of life (Constantinou et al. 2010; DiGironimo 2011; Ferreira Gauchía et al. 2006), whereas the idea of technology as applied science is the main distorted view (Constantinou et al. 2010; Ferreira-Gauchía et al. 2012). The analysis of the responses of the participants in this study, from Table 2, showed that their conceptions do not seem to be much different from those in the literature, with the primary conception being the instrumental conception of technology.

Instrumental Conception

This category corresponds to technology seen as a set or collection of tools, devices and machines (Ferreira Gauchía et al. 2006). This was the type of conception more typically present in the daily life of the participants and involved characterising technology as a set of products.

Of the 20 students who responded to the questionnaire, the responses of 13 were classified as representing the 'instrumental conception' of technology. Among such responses, nine directly mentioned the use of computers, tablets, mobile phones and videogames. Figure 4 depicts some representations of this type of conception, which was also characterised in the following written responses:

> To me, technology is to use the computer, the cell phone and similar stuff (A3, 11 years old, fifth grade).
> It's something very important, like the computer and the Internet, etc. (A11, 11 years old, sixth grade).

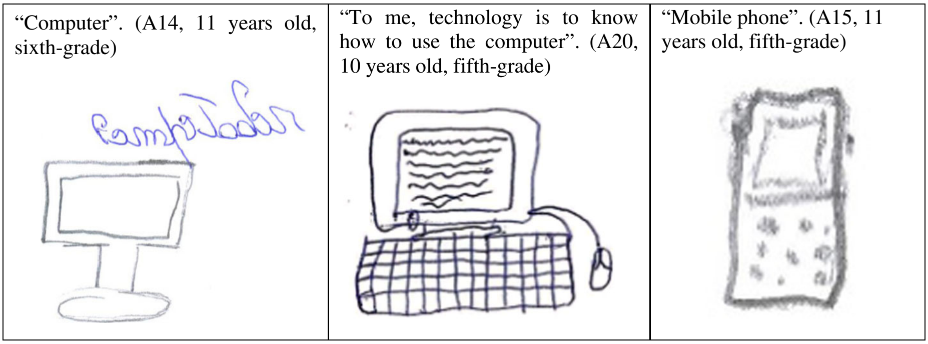


Fig. 4 Drawings representing the 'instrumental conception' of technology

PC, PlayStation, tablet. To me, it's like a digital book (A12, 10 years old, fifth grade).

Two participants associated technology with technological devices powered by electricity.

To me, technology is just electricity wires (A1, 12 years old, sixth grade).
Things that carry electricity (A5, 11 years old, sixth grade).

The instrumental conception also included representations that either tended to characterise the future or included science-fiction elements, with two responses (which were also classified as application of knowledge) corresponding to machines and equipment (Fig. 5).

The participants' responses included in this category tended to manifest a 'reductionist', purely instrumental view of technology. This instrumental perspective implies some consequences that deserve attention. One concerns the idea of technology as a set of instruments outside the corresponding social, political, economic and cultural context but assuming a neutral character detached from reality. The second consequence, also mentioned by Constantinou et al. (2010), is associated with the students' construction of the concept of 'technology'. More specifically, students usually have a vague idea of the meaning of that word, which additionally is often associated with devices—those powered by electricity in particular (computers, mobile phones, tablets, videogames, etc.)—that are a part of their daily lives. Such an instrumental conception of technology leads youths to express incomplete reasoning; for instance, they fail to recognise medicines and vaccines as technological products too (Constantinou et al. 2010).

The third and final consequence of this type of conception is that students see technology as instruments and technical devices and have difficulty establishing other associations, for example associations with scientific aspects, natural and artificial resources, etc. (Acevedo et al. 2003). Such relationships can only appear once students begin to ponder the context in which they live in the context of a science education closer to their reality, which is only possible when that reality is discussed, reflected and worked on by teachers or other social actors.

Cognitive Conception of the Nature of Technology

This is one of the types of conceptions most widely discussed in studies on science education (Acevedo et al. 2003; Constantinou et al. 2010; DiGironimo 2011; Ferreira Gauchía et al. 2006; Ferreira-Gauchía et al. 2012).

Among the responses given by the 20 participants in the study, five were considered as representative of the 'cognitive conception of technology'. The responses described below characterise technology as the application of theoretical knowledge. In the first three cases (A6, A8 and A9), technology is described as a direct application of knowledge (DiGironimo 2011; Ferreira-Gauchía et al. 2012; Gil-Pérez et al. 2005; Scherz and Oren 2006), whereas in the latter

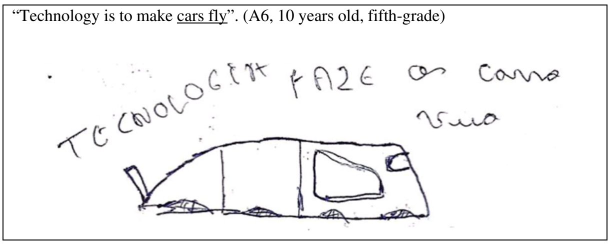


Fig. 5 Futuristic representation corresponding to the instrumental conception of technology

two, technology is represented as an instrument that contributes to the learning process, which thus justifies the name given to this category (Acevedo et al. 2003; Jonassen 2000).

> Technology makes cars fly (A6, 10 years old, fifth grade).
> To me, technology is intelligence and studying to create machines and other things (A9, 12 years old, sixth grade).
> It's a science that studies things (A8, 12 years old, sixth grade).
> Technology helps us learn better (A18, 12 years old, sixth grade).
> To me, technology is to know how to use the computer (A20, 10 years old, fifth grade).

The instrumental conception of technology presents us with the conventional image of the industrial products as its results, which are embodied in technological devices and elaborated according to fixed rules linked to scientific laws and theories. The actual results of that elaboration are that which characterise the cognitive conception of NOT, i.e. technology as an applied science. The students' statements clearly indicated that what the technological application has is supported by theory.

In the discussion of the theoretical framework of this study, we mentioned a hypothesis according to which present-day science and technology education fails in conveying the contemporary conceptions of NOS and NOT to the students (Constantinou et al. 2010; Ferreira Gauchía et al. 2006; Ferreira-Gauchía et al. 2012; Lederman 2007). This is partially because technology is presented as a set of techniques and devices that usually are the product of scientific knowledge without any connection to social and cultural aspects, thus becoming what we call applied science (Ferreira-Gauchía et al. 2012).

Gil-Pérez et al. (2005) note some hints that might help us understand the origin of the conception of technology as applied science among children and youths. According to those authors, science professors describe technology as applied science in their lessons. This conception often originates in technological books and science textbooks, or even in teacher training (Acevedo et al. 2003; DiGironimo 2011; Ferreira Gauchía et al. 2006; Ferreira-Gauchía et al. 2012).

In turn, the image of technology as a system for knowledge production (participants A18 and A20) is primarily characterised by the use of ICTs that are present in students' daily lives. This image involves a constructivist philosophical conception according to which technology is a 'cognitive tool' (Jonassen 2000). Jonassen (2000) conceptually defines cognitive tools as "computer-based tools and learning environments that have been adapted or developed to function as intellectual partners with the learner to engage and facilitate critical thinking and higher-order learning" (p. 21).

The 'instrumental' view of technology as a cognitive tool was detected in the interviews with the researcher (R), as shown by the following examples, which are taken from the narratives of two of the participants.

Sequence	Narratives
21	R: You've said that sometimes you feel you learn better through the use of some digital technology. When I say digital technology, do you know what it means? Sometimes, it seems to me you know but don't really know.
22	A1: It's the computer...
25	R: You feel that you learn more and better when you use the computer? What do you think?
26	A1: You don't get to learn everything, but you get to learn something.
27	R: And you, what do you think?
28	A2: Sometimes, there's more information in the internet.

In the example above, line 22 depicts the instrumental view of technology and sequences 26 and 28 represent the cognitive conception, as shown by A1's statement, "you don't get to learn everything, but you get to learn something" and A2's statement, "there's more information". There is a tendency among teachers to dismiss the role or use of technology in science teaching (Acevedo et al. 2003; Cachapuz et al. 2011). The exclusion of NOT from the school science curriculum impairs students' understanding of science, school science and their daily experience of technology.

Value-Based Conceptions of the Nature of Technology

Based on a personal instead of a rational or scientific point of view, the value-based conceptions of technology attributed to the students might have either a positive or a negative connotation. Three responses fit this category (12.5%), which expressed positive judgments on the 'conception of technology' as follows:

> It's something important (A4, 11 years old, fifth grade).
> It's cool! (A3, 10 years old, fifth grade).
> It's something very important, which is the computer and the Internet, etc. (A11, 11 years old, sixth grade).

To the participants, technology is something relevant, interesting, cool! Participants A4 and A13 did not specify the technology to which they alluded or how it is appropriated by them to acquire a 'positive value'. Participant A1 specified that the alluded technology, "the computer and the Internet" (instrumental conception), is characterised as something "very important". Why are the computer and the Internet so important? According to Pérez Gomez (2012), it is because they involve social relationships, even when they involve only virtual, more or less informative interactions with the screen, learning through discovery, inquiring, autonomous problem solving, rapidly acquiring technical skills, sharing challenges, tasks and goals, as is the case with most of the multiplayer games that youths like so much.

This was also the position of 11-year-old participant A03, which was manifested in the interview with the researcher (R).

Sequence	Narrative
87	R: You told me that you have a cell phone and that you use the computer here at DIC (Digital Inclusion Centre [Centro de Inclusão Digital–CID]) and at the shopping centre. When you're using the computer, what do you like to do most?
88	A: Access Facebook.
89	R: There's anything else you like?
90	A: YouTube.
91	R: And what do you do on YouTube?
92	A: I listen to music.
93	R: When you're at the computer, is there anything you don't have patience for or that you don't like to do?
94	A: Sometimes it gets on my nerves when I'm playing a game and I'm the point of moving to the next level and the computer shuts down.

The excerpt above shows that the participant uses ICTs primarily for communication purposes, to listen to music and to play games. The daily life of new generations, youth in particular, is highly mediatised by the Internet and social networks, which "elicit new lifestyles, modes of information processing, exchange, expression and action' (Pérez Gomez 2012, p. 65). Although to children and youths technology is cool, it poses a challenge to educational systems (schools, curricula, teachers, teaching and learning processes) in that we are already experiencing the 'exponential and accelerated explosion of information of the digital era and the concept of learning and the teaching processes must be substantially revised" (Pérez Gomez 2012, 69).

Systemic Conception of the Nature of Technology

According to Acevedo et al. (2003) and Ferreira-Gauchía et al. (2012), this category seeks to demonstrate less stereotypical conceptions of NOT and has five components: organisational-social, technical-methodological, scientific-technological, historical-cultural and verbal-iconographic.

The statements transcribed below show that two students manifested the 'organisational-social component' of the systemic conception of technology:

> To me, technology improves the way of doing things but also means expending a lot of energy (A2, 12 years old, sixth grade).
> To me, technology is something that works for people, for instance, computers, cameras, stoves, etc. (A12, 12 years old, sixth grade).

Although participant A19 also had an 'instrumental conception' of technology, in the first half of the statement technology appears as a factor that exerts decisive influence on the forms of social organisation. According to Acevedo et al. (2003), to consider technology as a system, taking its ethical and environmental implications into account enables placing it in a social context thus broadening its concept. Based on these notions, several authors suggest that one must consider science-technology-society (STS) relationships to provide students with a more contextualised view of science and technology (Abd-El-Khalick et al. 2001; Acevedo et al. 2003; Ferreira Gauchía et al. 2006; Ferreira-Gauchía et al. 2012), resulting in 'scientific and technological literacy' (Lederman 2007).

One participant manifested the 'technical-methodological component' of the systemic conception of technology:

> It's a way of discovering things (A10, 11 years old, fifth grade).

In that case, the student seemed to have a conception of science in which there is proximity between 'technology' and the acquisition of 'technical skills' to unveil and discover something that is a novelty. In other words, there is an implicit idea of the set of procedures and strategies needed to solve problems: "technology is a way of discovering things". An example of this view is 'Galileo's telescope' in the seventeenth century. Galileo was able to discover several celestial phenomena using that optical instrument, thus inaugurating a new era in astronomical observation in which that instrument supplied the basis for studies that provided the evidence for Copernicus's heliocentric system and resulted in Johannes Kepler's use of glasses and mirrors with conic surfaces.

Finally, the participants' responses did not include the scientific-technological, historical-cultural and verbal-iconographic components of the systemic conception of NOT. Perhaps the participants never had an opportunity to learn about some of the older crafts that produced technology-based science and changed various societies' lifestyles and relationships (Acevedo et al. 2003). The history of science contains various examples that allow an understanding of the scientific-methodological, historical-cultural and verbal-iconographic views of technology, which are often neglected in science and technology education.

Based on the data described here and aiming to facilitate children and youths' scientific and technological literacy in the contemporary world regardless of economic status, we suggest that education should start in the school environment to reach beyond the formal education setting. The outcomes related to advances in the understanding of science and technology improve when learning strategies are combined with the questioning of and reflections on distorted views (Driver et al. 1996).

Conclusion and Summary

This study sought to investigate not only students' views on science and technology but also how students characterise scientists' daily activities. Thus, we collected general information about students' views on the nature of science and technology and both analysed and assessed the possibility of using those views in educational settings that privilege students' mode of acting and thinking from a scientific perspective.

With respect to the analysis of the drawings of the scientists, it is worth noting that the participants' conceptions of the 'scientific activity' were mere exploration, observation and experimentation, which were not attributed to any setting other than the laboratory (or the classroom). The image of a scientist alone in a laboratory; with hair up, wearing glasses; performing some chemical experiment and is either intelligent, concerned or mad was present in participants' imagination. These are stereotypical views of scientific activity, which according to Buldu (2006) might influence the students' attitudes towards science.

With respect to NOS, we found stereotypical views characterised by empirical (marked by the development of methods; demonstration of facts; description of laws, theories and discoveries) and technical-instrumental (involving technological devices) conceptions of science. In addition, less stereotypical views were identified—in other words, we detected a tendency among children and youths to conceive of science as something that requires that 'cognitive and pedagogic aspects' (characterised as a body of knowledge—i.e. scientific content, school subject, etc.; understanding of reality, learning, etc.) be considered. Aspects such as the 'social and cultural' and 'creative and imaginative' conceptions of science were essentially absent. Such aspects tend to attenuate the stereotypical view of science because they consider either political, economic, social or ethical aspects or characteristics related to human imagination and creativity when constructing functional theoretical models.

Among the aspects that characterise NOT, we might emphasise not only the 'instrumental' view but also that of technology as an applied science, i.e. a direct application or a process of the application of technology. If the former is characterised as an instrumental tool, the latter becomes a cognitive tool; however, the idea related to the 'negative aspects of technology' is absent in the answers of the participants.

For teachers to construct—together with their students—less distorted conceptions of NOS and NOT that are in agreement with the contemporary science curricula, they should first be able to determine the students' previous knowledge of NOS and NOT (Akerson and Abd-El-Khalick 2005; Constantinou et al. 2010; Lederman 2007). In other words, they should be able to understand existing conceptions to then acquaint themselves with the conceptions held by their students. Knowledge of the students' conceptions allows teachers to better plan a type of teaching that is closer to science and technology education.

Based on the survey described in the first part of this chapter, one might say that there are similarities among the conceptions of technology, science and the scientist manifested by the children who participated in the described studies. In addition, many studies discuss the emergent curriculum—in which science and technology education has a significant place—wherein teachers are expected to develop a more complete and structured teaching of science and technology to overcome stereotypical views. It is expected that this type of teaching will initially target the youngest children.

Because the aim of our study was to identify youth and children's primary views of the role of the scientist, NOS and NOT, we next present some suggestions for students and teachers to overcome distorted conceptions that might provide the basis for future reflections. For example, Gil-Perez et al. (2001) describe some of the essential characteristics that guide the development of scientific literacy: (a) refusal of the notion of 'scientific method', (b) refusal of the idea of an empiricism that conceives of knowledge as the result of inductive inferences based on 'pure data', (c) emphasis on the role that research attributes to divergent thinking, (d) a search for globally coherent results and (e) an understanding of the social nature of scientific development. Those characteristics might be summarised following Driver et al. (1996), who describe three aspects that contribute to the understanding of science: (a) understanding some aspects of scientific content, (b) understanding of the scientific approach used in the research process and (3) understanding science as a social enterprise.

In addition, the review by Scherz and Oren (2006) indicates the following paths: (a) the introduction of socioscientific issues into the discussion on the nature of science, technology and the scientist's work; (b) the introduction of thematic activities to change students' attitudes about the societal relevance of science and technology; (c) the promotion of a realistic understanding of what science and technology can and cannot do, associated with a discussion of scientists' motivation; (d) the development of an interdisciplinary programme encompassing science subjects and relevant studies on science, technology and innovations and (e) the organisation of meetings between students and scientists to debate the role of the scientist in society.

In this regard, Acevedo et al. (2003) emphasise that to improve the understanding of NOS and NOT, it will not suffice for teachers first to admit that scientific activities comprise various technologies or a technological project and then to use scientific concepts and theories to solve contemporary problems. They must also provide further understanding of the meaning of NOS and NOT and include the social aspects of nature in their scope, given that these are human constructions. The reflection of teachers on the impact of science and technology on society and how they influence societal development ought to be promoted.

These are just some reflections on NOS and NOT in the school setting that deserve an in-depth exploration in the context of science education (in formal and non-formal settings) and that might become a relevant instrument to advance the understanding of the conceptions held by students and science teachers on this subject.

Finally, we are fully aware that the development of an instrument to analyse the participants' conceptions based on both the categories listed in Table 2 and their validation in a pilot test might represent limitations of this study. Future studies might focus on one topic in the special review and broaden the scope of research to complement the system of categories described in Tables 3, 4 and 5.

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Appendix A

Dear student,

The aim of this questionnaire is to identify your understanding of science education and the use you make of some technologies in your daily life.

We ask you to participate by responding this questionnaire. The data will be anonymous and confidential all along the process of analysis.

Understanding of science education

1. What is science to you? (You may write or draw).
2. What is the image you have of the scientist? (You may write or draw).

Understanding of the use of the computer and other digital technologies

3. What is technology to you? (You may write or draw)
4. Mark the technologies available at your home:

( ) Mobile phone	( ) DVD player
( ) Computer	( ) Educational DVDs
( ) Internet	( ) Educational CD-ROMs
( ) TV	( ) Game console
( ) Radio	( ) Digital games
( ) Stereo system	( ) Landline
( ) Tablet	( ) Other: ____________________

In the table below, indicate the frequency of the activities you perform with the computer when connected to the Internet

No.	Activities with computer	Never	Seldom	Sometimes	Often	Always
1	I use the computer.					
2	I use the computer to do school assignments.					
3	I use the computer to learn other subjects unrelated to school.					
4	I use the computer to read about various subjects.					
5	I use the computer to play.					
6	I use the computer to send e-mails.					
7	I use the computer to chat with friends and relatives.					
8	I use the computer to install and uninstall software.					
9	I use the computer to listen to music online.					
10	I use the computed to download online music and audio files.					
11	I use the computer to watch videos online.					
12	I use the computer to download online videos.					
13	I use the computer to connect to social networks (e.g. Facebook).					
14	I use the computer to meet new people in chat rooms.					
	Do you perform other activities with the computer that were not listed?					

Thank you for your collaboration.

Appendix B

1. Doubts about the questionnaire.
2. About the school: (a) characterisation of classes, (b) experimentation, (c) use of science textbooks, (d) homework, (e) group activities.
3. About ICT: (a) primary ICT available at home, (b) use of mobile phone, (c) use of computers, (d) main computer resources accessed, (e) computers at school.

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