

# Spanish students' conceptions about NOS and STS issues: A diagnostic study

Ángel Vázquez-Alonso  
*Universidad de las Islas Baleares, SPAIN*

Antonio García-Carmona  
*Universidad de Sevilla, Sevilla, SPAIN*

María Antonia Manassero-Mas and Antoni Bennàssar-Roig  
*Universidad de las Islas Baleares, SPAIN*

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Spanish students' beliefs on themes of Science-Technology-Society (STS) and nature of science (NOS) are assessed. The sample consisted of 1050 science and non-science students who had concluded their pre-university education (18-19 years old). Each participant anonymously answered 30 items drawn from the Questionnaire of Opinions on Science, Technology and Society, which were presented within two different booklets to cover the main STS-NOS issues. The students' direct responses were scaled by means of a multiple response model and a metric into a set of quantitative indices that represent the adequateness of the student's answer to current scholar knowledge on STS-NOS. The indices form the baseline variables on items, categories, and sentences for the quantitative and qualitative analyses of students' beliefs. The overall mean results display neutral positions, although a detailed scrutiny of the mean indices across items, categories, and sentences allows to pinpoint further rich details, such as the students' highest positive and lowest negative beliefs to be identified. The versatility of the method makes also possible to implement hypothesis testing, which in the present case do not find significant differences between science and non-science students. Some implications for research on the issues concerning the STS-NOS issues and its teaching and learning are discussed.

**Keywords:** assessment, NOS, science and non-science students, scientific literacy, STS interactions

## INTRODUCTION

The science-technology-society (STS) approach constitutes a meta-knowledge on science, technology and their interactions with society, which include a wide array of multidisciplinary issues drawn (mainly) from epistemology, sociology and history of science and

technology, but also from politics, ethics, psychology, etc. Aikenhead et al. (1989) consider the following topics as components of the STS approach: definitions of science and technology (S&T), external sociology of S&T (encompassing influence of society on S&T, influence of S&T on society, influence of school science on society), internal sociology of S&T (encompassing characteristics of scientists, social construction of scientific knowledge, social construction of technology), and epistemology of scientific knowledge.

All these topics could be reduced to two main groups, the STS interactions and the nature of science (NOS). However, these two groups cannot be viewed as sharply separated, non-interacting clusters, as they exhibit some relationships among them. In fact, many

Correspondence to: Ángel Vázquez-Alonso,  
Departamento de Pedagogía Aplicada y Psicología de  
la Educación. Universidad de las Islas Baleares, Palma,  
SPAIN  
E-mail: angel.vazquez@uib.es  
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### **State of the literature**

- Empirical research in science education has repeatedly and consistently shown that a persistent obstacle faced by NOS-STS teaching is that neither students nor teachers have a proper understanding of it.
- These negative findings are common to different countries and ages and leave no doubt about the severity of the problem in spite of the shortcomings of the tools and methods used and of the nuances and differences found among the different groups of students.
- Nevertheless, a diagnostic of Spanish students' understanding of STS-NOS had not been performed yet in order to check the current status of the question in Spain, and how efficient is the Spanish Education System to this aim.

### **Contribution of this paper to the literature**

- This study presents some main novelties for the assessment of beliefs on themes of STS and NOS: a new geographic setting (Spain), the use of an innovative methodology for gathering data, and diverse results about strengths and weaknesses of Spanish students' beliefs on STS-NOS issues.
- The COCTS instrument (a validated Spanish version of VOSTS) is applied in this study. It uses a multiple answer model, based on the scaling of the questionnaire sentences, and a standardized Likert-type scoring scale.
- An authentic context is implemented by the item stems which provide the contextual framework for the students' responses.

of the recent efforts to find out the main NOS traits that entail consensus among scholars include the STS interactions as a significant part of the consensually acknowledged NOS tenets. Lederman (2006, 2007) and colleagues usually apply in their research a list of consensual NOS tenets, which involve some epistemological features and a broad category that set up scientific knowledge as socially and culturally embedded (influenced by the society/culture in which science is practiced).

Similarly Bartholomew et al. (2004) have worked out, for teaching to pupils, another list of nine consensual NOS issues; they call them 'Ideas-about-science'. Among these, the STS interactions are displayed through the historical development of scientific knowledge. The "21st century Science" project states more openly the STS interactions under the 'Idea-about-science' so called "making decisions about science and technology" (Millar, 2005).

Further, technology appears to be so deeply intertwined today with science that some view both (S&T) as a new entity termed techno-science (Tala, 2009). Indeed, the validation and construction of scientific knowledge is very often influenced by the performance and operation of scientific technologies (instrumentation) and their relationships with society. Thus, the NOS concept should be enlarged to emphasize, not only the strict epistemology of science, but also the relationship of science with technology and society. In this integrated framework, the NOS field could also be recognized as heir to and converging with the educational goals of the STS orientation, such as to improve public understanding of S&T in today's world, which includes understanding the concepts, impacts, and solutions of S&T (social, environmental, economic, cultural, etc.), and the relationships between science and technology (National Science Teachers Association [NSTA], 2000; Spector et al., 1998).

Thus, NOS involves a set of multidisciplinary issues about what science is, how scientists do their job, and how science works and interacts with society and technology in today's world. For most of recent research literature, the central theme of NOS is the philosophical principles that underlie the validation of scientific knowledge (epistemological tenets of science), but also refers to the broad field of STS interactions, the characteristics of the scientists and the scientific community, as these latter issues determine the former (the tenets). All in all, beyond the simplicity of one or another label (NOS or STS), this rational evidences a broad increasing confluence between STS orientation and mainstream NOS research that currently suggest a kind of big overlapping between NOS and STS labels.

Scholars in science education consider the understanding of NOS an important educational goal, as it is a basic component of scientific and technological literacy for all (Millar & Osborne, 1998). For including NOS issues in the educational curriculum have been suggested several reasons (cognitive, utilitarian, democratic, cultural, axiological, comprehensive). However, the overriding rationale is to promote S&T literacy for all in the sense that quality science education needs to develop important adequate beliefs and positive values on the public understanding of S&T, in a world that is increasingly saturated by science (Acevedo et al. 2005). The educational reforms in many countries since the last decade of the twentieth century have taken up these educational goals in their school curricula (American Association for the Advancement of Science [AAAS], 1993; Department for Education and Employment, 1999; National Research Council [NRC], 1996; NSTA, 2000).

Further, NOS is still an innovative element in science education, which adds certain difficulty to its teaching (McComas & Olson, 1998). The complex,

interdisciplinary, provisional, and evolving meta-knowledge status of NOS issues often projects an image of controversy and lack of consensus among philosophers, historians, sociologists, and science educators (Alters, 1997; Eflin et al., 1999; Vázquez, Acevedo, Manassero, & Acevedo, 2001). Obviously, disagreement among the experts represents a serious handicap for teaching NOS, as it makes harder to plan teaching and learning NOS, especially in deciding on the curriculum contents. On the other hand, some studies suggest that there are also some areas of agreement that could form the basis for building a consensus science curriculum, avoiding educational unnecessary problems of complexity and controversy (Bartholomew et al., 2004; Eflin et al., 1999; McComas & Olson, 1998; Rubba et al., 1996).

Empirical research in science education has repeatedly and consistently shown that a persistent obstacle faced by NOS teaching is that neither students nor teachers have a proper understanding of NOS. Since the early 1970s, there has been a constant stream of evidence for students' scant understanding of the theories, hypotheses, laws, and methods of science (see, for instance, Mackay, 1971; Rubba & Andersen, 1978; Wood, 1972). These negative findings are common to different countries and ages (Lederman, 1992; García-Carmona, Vázquez & Manassero, 2012), and leave no doubt about the severity of the problem in spite of the shortcomings of the tools and methods used (Manassero et al., 2001) and of the nuances and differences found among the different groups of students. Aikenhead (1987) and Fleming (1987) highlight the difficulty of students to distinguish between science and technology and STS relations, while others detected some problems on understanding epistemological issues about the role of the scientific method, theories and hypotheses, models, creativity, and the provisional nature of scientific knowledge (Bell et al., 2003; Kang et al., 2005; Lederman & O'Malley, 1990; Moss et al., 2001; Ryan & Aikenhead, 1992; Schoneweg-Bradford et al., 1995; Zoller et al., 1991).

Diagnoses of students' understanding of STS-NOS have mostly been performed using small research samples, mainly of science students. In a pioneering study, Korth (1969) applied the Test on Social Aspects of Science (TSAS) to a secondary school sample of science and non-science students. The conclusion reached was that science-oriented students have significantly better attitudes toward science, better understanding of the nature of the scientific enterprise, and more realistic view of scientists than their counterparts, although they also showed a lack of understanding of important social aspects of science and technology. However, confidence in these results has to be tempered by the low reliability of the scales and the study's use of a non-robust comparison test (chi-

squared). More recently, Holbrook, Rannikmäe & Rannikmäe (2006) studied the NOS views of non-science students, and Liu and Tsai (2008) compared arts and science graduate students (including an initial teacher education group) using a multidimensional instrument. Overall, the two groups were not found to differ from each other. Science students have less sophisticated beliefs in some NOS aspects, such as the cultural dependency of scientific theories.

The present study examines the beliefs on themes of STS and NOS of a large sample of Spanish science and non-science students within the framework of an international project (Vázquez, Manassero, & Bennassar, 2009). To this end, a set of items was selected from the Cuestionario de Opiniones sobre la Ciencia, la Tecnología y la Sociedad (COCTS) (Questionnaire of Opinions on Science, Technology & Society).

### Research Questions

The study was guided by the following research questions:

*What, in general, are the strengths and weaknesses of Spanish students' beliefs on themes of STS-NOS?*

*Are there major differences between the beliefs of science and non-science Spanish students on themes of STS-NOS?*

## METHODS

### Context and Sample

In Spain, STS and NOS issues were not included in official pre-university syllabuses until recently with the Education Act of 2006 and its curricular development during 2007 and 2008. Moreover, the current presentation of STS-NOS content in school science curricula is still far from well structured if compared with other curricular efforts towards the same goal (AAAS 1993; Millar & Osborne 1998).

In Primary Education (6-12 years), the national science curriculum does indeed make some allusions to the NOS and to STS relationships in the guidelines it sets out for curriculum development. However, it does not actually include anything on these topics in its proposal of content. In Compulsory Secondary Education (12-16 years), the national science curriculum sets out for each course a specific block of content referring to NOS and STS relationships. The blocks are integrated transversally into other contents. It needs to be said that science subjects are not compulsory in the last year of this stage (16 years), so that many pupils do not study science beyond 15 years old.

Finally, in the non-compulsory secondary education stage of "Bachillerato" (16-18 years), the pupils have the choice between two study paths –one of science and technology, and the other of arts and humanities- so

that only a part of these pupils study science. There is, however, a common subject for both paths called "Science for the Contemporary World". This includes content that explicitly deals with STS interactions and the NOS. In addition, the subjects of Physics, Chemistry, Biology, and Geology for the science pupils include a specific block of STS and NOS content. Therefore, it can be assumed that science students have more contact with STS-NOS content than humanities students do at this educational stage.

Consequently, one would expect Spanish science Bachillerato pupils to acquire better and broader knowledge of STS and NOS content than the arts and humanities pupils. This, however, is a hypothesis that is yet to be tested, as it is proposed in the present study. In particular, we set out to investigate the STS and NOS conceptions of science and non-science pupils who had completed Bachillerato recently in the current educational framework. The ideal population for such a study was that of undergraduates just at the beginning of their university course.

The study was possible thanks to the collaboration of teachers at different universities in Spain. These teachers were asked to encourage their students to voluntarily respond to a selection of items from the COCTS, as will be seen below. The students had two options for responding these items: written responses on paper, or through a computer application that presented the items and coded the responses. The resulting valid sample of participants consisted of 1050 students (650 women and 400 men) that were first year university undergraduates (18-19 years of age); 420 were science students and 630 non-science students.

### Research instrument

The Spanish "Questionnaire of Opinions on Science, Technology and Society" (Spanish acronym COCTS) is a 100-item pool that is a faithful translation and adaptation into the Spanish language and cultural context (Vázquez, Manassero & Acevedo, 2006) of the 114-item "VOSTS: Views on Science, Technology and Society" (Aikenhead & Ryan, 1992; Aikenhead, Ryan & Fleming, 1989), and the 10-item "TBASTS: Teachers' Conceptions about Science-Technology-Society" (Rubba & Harkness, 1993; Rubba, Schoneweg & Harkness, 1996). The VOSTS and TBASTS questionnaires were developed empirically from interviews and open responses given by students and teachers, synthesized in the multiple-choice statements conforming the items. The VOSTS questionnaire is structured into nine dimensions (leftmost column of Table 1).

The main body of COCTS comes from VOSTS, a 114-item pool that has also been adapted to different international contexts such as Quebec (Aikenhead, Ryan

& Désautels, 1989), Portugal (Nunes, 1996), Spain (Manassero & Vázquez, 1998), the United Arab Emirates (Haidar, 1999), Taiwan (Lin & Chen, 2002), Nigeria (Mbajiorgu & Ali, 2002), Brunei (Tairab, 2001a, 2001b), and Lebanon (Abd-El-Khalick & BouJaoude, 1997), and is increasingly being applied in science education research (Celik & Bayrakçeken, 2006; Dass, 2005; Dogan & Abd-El-Khalick, 2008; Martin-Hansen, 2008; Tedman, 2005). Lederman, Wade and Bell (1998) consider VOSTS to be a valid and reliable instrument for investigating positions on STS-NOS issues. Botton and Brown (1998) established its empirical reliability.

The COCTS items have similar, but not equal, multiple-choice formats. The item stem poses an STS-NOS issue, using a common and simple language in a non-technical style. There follow a number (variable from one item to another) of statements, each labeled with a letter A, B, C... Each statement states a particular reason explaining a specific position (conception) on the stem issue (Manassero, Vázquez, & Acevedo, 2003). To get a balance between avoiding respondents' fatigue in answering the research instrument and covering acceptably all the dimensions of the pool, a set of 30 COCTS items were selected and assigned to two different forms (15 items each), Form 1 (F1) and Form 2 (F2) (Table 1), which contain 200 statements.

The structure of the original VOSTS was used here to classify the items into three main dimensions (left column of Table 1), which correspond to the two underlying component fields of STS-NOS, that is, STS interactions (Dimensions a and b) and epistemology of scientific knowledge (Dimension c). Each single item is labeled by a five-digit number, whose first digit identifies the dimension –1 to 8 for different aspects of STS (internal sociology of science, etc.) and 9 for NOS– the second digit corresponds to themes, and the third digit to the sub-themes of each item (science, technology, etc.). Each statement within an item is identified by the set of five digits corresponding to the item it belongs to, plus the letter that represents the position of the statement within the item (example in central column of table 3). Moreover, some statements include the coding `_C_` inserted before the tag number, which means the statement represents an idea that achieved the judges' consensus (the group of expert judges strongly agreed on the category they assigned to the statement).

A series of previous studies verified the validity of COCTS (Vázquez et al., 2006; Vázquez et al., 2013).

### Response and metric

COCTS applies a new multiple response model (MRM) –the respondent rates each statement in the item– which provides more accurate and extensive information about the respondent's thinking. The MRM

**Table 1.** Labels of the items included in the two questionnaire forms –Form 1 (F1) and Form 2 (F2)– as correspond to the overall COCTS dimensions providing the general structure of the issues.

Dimensions	Form 1 (F1) Items		Form 2 (F2) Items	
	Sub-themes	Cronbach's alpha	Sub-themes	Cronbach's alpha
a) Definition of science and technology	F1_10111 science	0.22	F2_10211 technology	0.84
	F1_10411 interdependence	0.32	F2_10421 interdependence quality of life	0.88
b) Science–Technology–Society interactions	F1_30111 STS interactions	0.77		
b.1) Influence of society on S&T	F1_20141 country's government politics	0.29	F2_20211 industry	0.87
	F1_20411 ethics	0.94	F2_20511 educational institutions	0.89
b.2) Influence of S&T on society	F1_40161 social responsibility for pollution	0.45	F2_40131 social responsibility information	0.79
	F1_40221 moral decisions	0.70	F2_40211 social decisions	0.91
	F1_40531 social well-being	0.73	F2_40421 application to daily life	0.88
b.3) Internal sociology of science			F2_50111 union two cultures	0.85
	F1_60111 motivations	0.89	F2_60521 gender equality	0.89
	F1_60611 women's under-representation	0.50	F2_70211 scientific decisions	0.89
	F1_70231 consensus decisions	0.75	F2_70711 national influences	0.86
c) Epistemology	F1_80131 advantages for society	0.75		
	F1_90211 scientific models	0.92	F2_90111 observations	0.86
	F1_90411 tentativeness	0.48	F2_90311 classification schemes	0.89
	F1_90621 scientific method	0.85	F2_90521 role of assumptions	0.83
			F2_91011 epistemological status	0.78

*Note: There exists a correspondence between each dimension and the first figure of the item label. A short description of the item content (sub-themes) follows each key.*

avoids “forced” choices that misinform the researcher about the respondent's thinking. The MRM asks participants to express their agreement / disagreement with each statement within each question on a nine-point scale (1 to 9, disagreement to agreement). If a respondent does not wish to answer, he/she may choose one of two reasons for not evaluating the statement (I do not understand the issue or I do not have sufficient knowledge about the issue) or leave it blank. The scaling of COCTS statements is categorized into one of three levels: Appropriate (A): the statement

expresses an adequate view; Plausible (P): though not very adequate, the statement expresses some acceptable aspects; and Naïve (N): the statement expresses a view that is neither adequate nor plausible.

Each direct agreement statement score (1-9) is transformed into a homogeneous invariant normalized statement index within the interval [-1, +1] through a scaling procedure that takes into account the category of the statement (Adequate, Plausible, Naïve) previously assigned by a panel of expert judges (further details have been presented elsewhere (Vázquez et al., 2006). For

**Table 2.** Correspondence between direct scores and scores of views (A, P, N), according to the category (Adequate, Plausible, or Naïve) of each sentence, and computation of the normalized index of the sentence (A', P', N').

Direct Score Scale Degree of agreement										
Total	Near Total	High	Partial High	Partial	Partial Low	Low	Near Null	Null		
9	8	7	6	5	4	3	2	1		
Correspondence with scores of views										
Categories	Direct scores of views (A, P, N)									Normalized index
Adequate	4	3	2	1	0	-1	-2	-3	-4	A'=A/4
Plausible	-2	-1	0	1	2	1	0	-1	-2	P'=P/2
Naïve	-4	-3	-2	-1	0	1	2	3	4	N'=N/4

instance, an appropriate statement expresses an adequate view on the issue, thus the scaling procedure assigns the index score +1 to total agreement (9) and -1 to total disagreement (1), and proportionally for the in-between scores. A naïve statement expresses a view that is neither adequate nor plausible, so that the scaling assigns a scoring index that is the inverse of that of the appropriate statements. A plausible statement assigns the +1 scoring index to the middle direct score (5) and -1 to the two extremes (1, 9), and proportionally for the in-between scores (see table 2). This scaling procedure is common for Likert attitudinal scales that use multi-directional statements, to avoid revealing the “right position” through convergent statements (Eagly & Chaiken, 1993).

The value of the index represents the degree of match between the respondent’s opinion, which was expressed originally through the direct agreement score, and the current conceptions of experts on HPSST. The higher (lower) the index, the better (poorer) is the match between the respondent’s view and the experts’ conceptions on HPSST, no matter which kind of original statement generated it (invariant). Thus, the closer to the maximum positive value (+1) an index is, the more informed (closer to experts’ conceptions of STS-NOS) is the respondent’s view; while the closer to the negative value (-1) the index is, the more misinformed (detached from current STS-NOS conceptions) is the respondent’s view (Vázquez et al., 2001). As misinformed conceptions are associated with low negative values of the index, and informed conceptions with high positive values of the index, for brevity, the former are often simply referred to as “positive”, and the latter as “negative”, with no implication of any meaning of bias.

The statement indices form the basis for further computations and statistics. For instance, three category indices (adequate, plausible, and naïve) are computed for each item by averaging the indices of the statements that belong to the same category (e.g., the average of the statement indices that belong to the appropriate category produces the appropriate category index, and

so on for the plausible and naïve categories in each item). This computation produced 87 category indices for the two forms (a few items lacked one category). Furthermore, the average of the category indices for each item produces the weighted item overall index, which is the quantitative value of the overall conception about the item's issue (30 overall indices for the two forms). In sum, to each item there correspond a number of statement indices (one index per statement), three averaged category indices, and one weighted item index. For the whole application, 99 statement indices for F1 (101 for F2), 43 category indices for F1 (and 44 for F2), and 15 item indices for each form help to pinpoint the respondent’s conceptions of STS-NOS. The reliability (Cronbach's alpha) computed from the statement direct scores for the whole form was fairly good (0.88 for F1 and 0.97 for F2); however, the single item reliability was lower and much more variable, an unsurprising result as the reliability decreases when the number of statements of the sub-scales decreases (see Table 1).

### Statistical analysis

The indices provide homogeneous, invariant, and normalized interpretations of the scores across all statements, categories, and items, i.e., the magnitude of the correctness of a conception. The index scores allow the variables to be averaged and interrelated, and inferential statistics to be applied for hypothesis testing, group comparison, or to establish cut-off points for achievement levels (Vázquez et al., 2006). Inferential statistics is usually reported through probabilistic measurements of the significance of differences (p-values) which do not provide any information about how large or small a difference is. This information is provided by the effect size (difference between means expressed in units of standard deviations), which allows the magnitudes of the differences to be compared across variables and groups. The effect size statistic is usually applied by means of some simple benchmarking criteria (Cohen, 1988) that classify differences in intervals labeled as trivial ( $d < 0.10$ ), small ( $d < 0.20$ ),

medium ( $d < 0.5$ ), large ( $d < 0.8$ ), etc. For the samples and indices in this present study, an effect size of over 0.30 corresponds to statistically significant differences ( $p < 0.01$ ). We shall henceforth use the word “relevant” to refer to differences that satisfy both the effect size criterion (greater than 0.30) and the statistical significance criterion of  $p < 0.01$ . Scores or differences below this threshold will be considered irrelevant, even though they might still be statistically significant or interesting from other points of view (e.g., personal evaluation).

Therefore, the quantitative methodology used to assess STS-NOS conceptions based on the MRM model offers the researcher sounder, more accurate, and fuller information on the respondent’s conceptions of an STS-NOS issue than a single response model. Furthermore, since the assessment is constructed from the scores on all statements, the set of invariant multiple indices (statement, categories, and overall item indices) provides valid and reliable overall quantitative evaluation data that are solidly based on well-founded measurements and allow the application of statistical hypothesis testing. The method thus ensures the clarity and comparability of the results, facilitating their qualitative analysis and discussion.

See, by way of example, the complete analysis of one of the items in Table 3.

## RESULTS

### Overall analysis

Many (26% of the questionnaire total) of the belief indices of the sentences are positive and above the 0.50 standard deviation relevance threshold, but far fewer (7%) of the negative position indices surpass this threshold. Most of these sentences with positive indices belong to the appropriate category, although there are also some naïves sentences. Also noteworthy in this group of highly positive indices is the absence of plausible sentences.

Sentences with highly positive indices have common features that stand out as interesting for three reasons. Firstly, one notes four repeated items (e.g., 20141, 40161, 60611, 60521) which each have three or more position statements in this highest positive index group. The first (20141) refers to the influence of a country's government politics on S&T, the second (40161) to social responsibility for pollution, the third (60611) to the under-representation of women in the S&T system, and the fourth (60521) to equality between men and women as scientists. Secondly, practically all items have at least one of their sentences among this positive index group, i.e., for nearly every item there is some opinion which is very positive. The exception is item 20411 referring to the influence of the cultural context's religious and ethical beliefs on scientific knowledge

**Table 3.** Text of item 90621 (scientific method), displaying the text of sentences (centre), the sentence labels (left column), the category assigned to each sentence (second column left), and the mean indices for the whole sample of the sentences, the three categories and the whole item (right)

Variable	Category	Item	Mean indices		
			Sentence	Category	Global
		90621 The best scientists are those who follow the steps of the scientific method.			
F1_C_90621A_N_	Naïve	A. The scientific method ensures valid, clear, logical and accurate results. Thus, most scientists will follow the steps of the scientific method.	-0.61	-0.57	-0.104
F1__90621B_N_	Naïve	B. The scientific method should work well for most scientists; based on what we learned in school.	-0.53		
F1_C_90621C_A_	Appropriate	C. The scientific method is useful in many instances, but it does not ensure results. Thus, the best scientists will also use originality and creativity.	0.51	0.51	
F1__90621D_P_	Plausible	D. The best scientists are those who use any method that might get favourable results (including the method of imagination and creativity).	-0.26	-0.25	
F1__90621E_P_	Plausible	E. Many scientific discoveries were made by accident, and not by sticking to the scientific method.	-0.24		

Note the letters (A, B, C, D,...) that follow the question number and serve to identify each sentence within the question as well as the following set \_A\_, \_P\_ or \_N\_, which inform on the sentence category (appropriate, plausible or naïve)



which has no sentence among the highly positive. And thirdly, more than half of these sentences with the most positive indices correspond to statements that met consensus among the judges (these statements are identified by the inclusion of "\_C\_" in their identifying label).

A sample of the most positive beliefs: the three ideas that present the highest indices refer to environmental conservation, pollution by heavy industry, and the transfer of this contamination to other countries. The argument held, appropriately and very positively, is that there are three reasons why heavy industry should not be moved out to developing countries: because the effects of contamination are global, because pollution should be reduced or eliminated wherever it occurs, and because pollution should be limited as much as possible.

There are far fewer sentences (about 7% of the total) with negative indices well below the threshold. Most of the sentences with very negative indices belong to the Plausible category, but there are also some of the Naïve category. It is notable that appropriate sentences are absent from this group, and that there are two items (60611 and 60521) referring to the theme of women in S&T with many of their sentences in this group of negative indices. In addition, some of these negative beliefs correspond to ideas that achieved the consensus of the judges, i.e., ideas about which there is no controversy since the experts all consider them Naïve beliefs of S&T.

Sentences with very negative indices have common features that stand out for various reasons, and which are similar to the features described above for the very positive statements. In particular, some items have several of their sentences in this most negative index group (i.e., 60611, 60521). One also notes that a given item can have at the same time sentences showing very positive and very negative beliefs, a finding that points out to the inconsistency of these beliefs on STS-NOS issues. The following are some of the sentences with the most negative indices, i.e., representing the most inappropriate beliefs:

*Scientists investigate mainly to discover new ideas or invent things to benefit society.*

*Most scientists follow the steps of the scientific method because it ensures valid, clear, logical, and accurate results.*

*Scientists convince other scientists by presenting conclusive evidence in support of the theory.*

*There is no reason to have more men than women scientists because they are equally capable and have similar opportunities.*

Regarding the category indices, the categories with the highest positive indices comprise almost all the appropriate categories of each item together with a few naïve categories. Consequently, by exclusion, most of

the naïve categories and, to a lesser extent, the plausible categories present the most negative indices. The disproportion in the number of very positive (far more) and very negative (far fewer) categories reflects the moderately positive overall trend also seen in the grand averages and the item indices, as will be seen below.

On the other hand, the analysis of the mean scores in each of the items allows one to identify the themes with the most positive and the most negative indices. The most positive values correspond to the following items (in decreasing order of mean index):

*F1\_40161 social responsibility: pollution*

*F1\_30111 STS interactions*

*F1\_20141 country's government politics*

*F1\_10111 science*

*F1\_40221 moral decisions*

*F1\_60611 women's under-representation*

*F2\_40131 social responsibility information*

*F2\_60521 gender equality*

*F2\_50111 union two cultures*

*F2\_10421 interdependence quality of life*

*F2\_20211 industry*

Most of the items have positive mean indices. Only a few exhibit negative mean indices, but all their values are very close to zero, so that one may conclude that there are no themes whose beliefs are very negative or naïve.

### Analysis of contrasts

As was noted in Methods, the sample analyzed comprised two different groups of students: science and non-science students. In the following paragraphs, the results for these two groups are presented.

To describe the differences between science and non-science students, we shall present in order the results for the sentences, categories, and items. As one observes in Table 4, in general, the means and standard deviations are similar between these two groups of students (this is so for all the index classes – item, category, and sentence– and for questionnaires F1 and F2). Therefore, one can say, first, that the respondents to F1 and F2 have almost identical indices in all the variables they contain, and, second, that these students have overall beliefs about themes of STS-NOS that are only minimally reasonably informed. One also observes in the table 4 that the overall effect sizes for the differences between science and non-science groups are practically null for all the indices (items, categories, and sentences). This is indicative of a practical absence of overall differences between the two groups, although it is compatible with differences in favour of one or the other in certain variables that offset each other to produce the observed almost null overall differences.



**Table 4.** Overall results of the statistical significance and effect size (difference of the means in standard deviation units) of the differences between the science and the non-science groups in the mean item, category, and sentence indices of questionnaires F1 and F2 (N = 1050)

	Science students		Non-science students		Total		Sig.	Effect size
	Mean	S.D.	Mean	S.D.	Mean	S.D.		
F1 Sentences	0.117	0.574	0.116	0.581	0.116	0.579	0.465	0.001
F1 Categories	0.104	0.469	0.102	0.475	0.103	0.473	0.457	0.005
F1 Items	0.094	0.286	0.092	0.294	0.093	0.291	0.438	0.009
F2 Sentences	0.038	0.649	0.039	0.605	0.039	0.636	0.388	-0.007
F2 Categories	0.077	0.512	0.079	0.486	0.078	0.504	0.431	-0.007
F2 Items	0.072	0.308	0.075	0.281	0.074	0.296	0.409	-0.018

**Table 5.** Overall results of the statistical significance and effect size (difference of the means in standard deviation units) of differences between science and non-science groups in the sentence, category and item indices of questionnaires F1 and F2 (N= 1050)

	Significance ( $p < .01$ )	Effect size ( $d > .20$ )
<i>Sentences</i>		
F1__10411E_P_interdependence	0.0072	0.2381
F1_C_90211C_I_scientific models	0.0058	-0.2576
F1__90621B_I_scientific method	0.0053	-0.2587
F1_C_90211B_I_scientific models	0.0029	-0.2809
F1__90211D_P_scientific models	0.0003	-0.3369
F2__10421C_P_interdependence quality of life	0.0053	-0.2395
F2__40421G_A_application to daily life	0.0006	-0.2995
F2__40421F_P_application to daily life	0.0006	-0.3009
F2__10211B_I_technology	0.0000	-0.4138
<i>Categories</i>		
Plausible Index: interdependence F1_10411PL	0.0072	0.2381
Naïve Index: scientific models F1_90211IN	0.0073	-0.2473
Naïve Index: scientific method F1_90621IN	0.0053	-0.2551
Naïve Index: technology 10211IN	0.0000	-0.4138
<i>Items</i>		
F1_10411 interdependence	0.0006	0.3016
F1_90211 scientific models	0.0027	-0.2821
F2_10211 technology	0.0032	-0.2547

Note. Letters between underscores indicate the Appropriate \_A\_, Plausible \_P\_, or Naïve \_N\_ category assigned to each position; \_C\_ denotes positions whose category was fully agreed on by the expert judges

Only nine sentence indices show statistically significant differences ( $p < .01$ ) between science and non-science students (Table 5). The effect size is small for most of these nine sentences, with only three sentences surpassing the 0.30 threshold. Moreover, these three effect sizes are all negative, indicating that the non-science students have better and more positive beliefs concerning scientific models, the application of science to everyday life, and the conception of technology than their science colleagues.

Very few categories have indices showing statistically significant differences ( $p < 0.01$ ) between science and non-science students (only 4 cases). Three present negative effect sizes. This indicates that non-

science students have better-informed beliefs about these three cases (scientific models, scientific method, and conception of technology) than their science colleagues. Nonetheless, this difference is relevant (with an effect size exceeding the 0.30 threshold in absolute value) only for the naïve category on the conception of technology. The case favourable to the science students (the interdependence between S&T) does not reach relevance in its difference with respect to the non-science students (the size effect does not exceed the 0.30 threshold).

The three items whose belief indices present statistically significant differences ( $p < 0.01$ ) between science and non-science are also summarized in Table 5.

Only one of these items, that on the interdependence of science and technology, does the effect size exceed the 0.30 threshold, being positive and hence favourable to the science students. The other two items (referring to scientific models and the conception of technology), with effect sizes less than the threshold in absolute value, are negative, indicative slight superiority of the non-science group in their beliefs on these aspects.

In sum, there are practically no differences between science and non-science groups. The overall indicators of the size of the differences between the two groups are practically zero. The analysis of the three hundred or so variables revealed statistically significant differences only in the 16 cases presented in the table 5; only four of these cases did the effect size represent relevance ( $d > .30$ ).

## DISCUSSION

Most previous investigations have revealed, more or less explicitly, a very negative vision of students' beliefs about STS-NOS, highlighting the prevalence of misinformed and negative beliefs (Ryan & Aikenhead, 1992; Lederman, 1992, 2007; among others). Perhaps this is because the analysis focused on identifying certain abstract features of STS-NOS (tentativeness, creativity, scientific method, social influences, relationship with technology, empirical foundations, theory-laden aspects, positivist empiricism, etc.) that are usually far removed from the students' experience. The present study paints a somewhat different and more complex picture: both negative (inappropriate) and positive (appropriate) beliefs coexist in all the STS-NOS issues studied. It also found multiple different beliefs – not in an abstract context - but in the various specific contexts set out in each item as a framework for the responses.

The grand averages of the indices were close to zero in value, although this apparent neutrality hid a balance between positive (appropriate) and negative (inappropriate) beliefs. In general, the students showed quite appropriate beliefs for about a quarter of the sentences presented in the questionnaires, very inappropriate ideas for just under one-tenth of those sentences, and relatively neutral beliefs in the remaining cases. Therefore, the novel contribution of the present study is the detection of appropriate or well-informed beliefs, as had been anticipated in some previous studies (Manassero & Vázquez, 1998; Manassero et al., 2001; Moss et al., 2001). Furthermore, the overall analysis of the items showed that there were no STS-NOS themes where the students' beliefs were very negative.

The students' most positive (appropriate) beliefs are related to the following STS-NOS topics:

- ✓ *Influence of a country's government policies on S&T*
- ✓ *Social responsibility regarding the contamination and other environment problems*
- ✓ *Women underrepresentation in S&T*
- ✓ *Equality of capacities between women and men for science*

In addition, the students' most negative (inappropriate) beliefs are related to the following STS-NOS topics:

- ✓ *Scientists' motivations to do their investigations*
- ✓ *Application of scientific method in science*
- ✓ *The importance of presenting conclusive evidence for convincing scientists to support a theory*
- ✓ *Reasons for justify the existence of more scientific men than scientific women*

In addition to evaluating the level of the students' beliefs about themes of STS-NOS, we compared the results according to the students background in science or non-science. There were no significant or relevant differences between the science and humanities students' beliefs. It suggests that the science path in Spain's Bachillerato (16-18 years) does not seem to contribute to any substantial improvement in the understanding of STS-NOS. This result was predictable bearing in mind that, on the one hand, the scanty effective integration of STS-NOS issues in the current science curricula (García-Carmona et al., 2012; Lederman, 2006), and, on the other hand, previous studies that have compared science and non-science students' ideas about STS-NOS in other countries (e.g., Holbrook et al., 2006; Liu & Tsai, 2008).

From the perspective of the overall analysis, the study showed that most of the students' negative and poorly informed beliefs about STS-NOS issues correspond to sentences categorized as naïve and plausible, while their positive and well-informed beliefs correspond mainly to sentences categorized as appropriate. The students' thus seem better able to identify the positive ideas, i.e., the appropriate sentences, than the naïve or plausible sentences. This asymmetry reflects some superficiality and ambivalence in the students' beliefs on themes of STS-NOS: they identify the appropriate ideas, but they are not equally able to reject in a similar proportion other opposing ideas on the same topic, which they should have rejected merely due to the logical incompatibility with the appropriate viewpoint. Further, the students often agree, at the same time, with logically incompatible appropriate and naïve sentences on an issue, without apparently perceiving the contradiction. This ambivalence on belief is typical of issues involving values and attitudes, and lies at the root of the difficulties observed in teaching STS-NOS topics (Apostolou & Koulaidis, 2010; Gess-Newsome, 2002; Khishfe & Abd-el-Khalick, 2002, Lederman, 1992; Meichtry, 2006).

Indeed, ideas on STS-NOS are complex entities (a meta-knowledge) which resist representation under a single general label, and are hard both to teach and to learn. Proposals for teaching STS-NOS through explicit and reflective activities fit in well with this notion: implicit teaching is insufficient because reflection is a sine qua non to overcoming the contradictions and ambivalences of complex thinking (e.g., Abd-El-Khalick & Lederman, 2000; Akerson & Volrich, 2006; Schwartz et al., 2004). STS-NOS ideas should be directly and clearly presented (explicit teaching), and to be effective, time should be devoted to deliberation activities on STS-NOS content (reflective teaching).

In general, the students exhibited numerous uninformed beliefs on STS-NOS that mostly arose from their adherence to Naïve or Plausible sentences. Nevertheless, they also exhibited informed beliefs in their clear agreement with many of the appropriate sentences. This finding not only gives a positive twist to the generally negative results reported from previous investigations, but also educationally is also good news because these informed beliefs can be used pedagogically, in planning and teaching the STS-NOS curriculum, as key structural hooks for the change and reconstruction of the negative beliefs to achieve meaningful learning.

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<sup>i</sup> The set of 30 items selected from COCTS in the study is available at: <http://www.oei.es/COCTS/esp/index.html>