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Students' Attitudes toward Science, Technology, and Society, Evaluated through a Multiple-Response Model

Actitudes del alumnado sobre ciencia, tecnología y sociedad, evaluadas con un modelo de respuesta múltiple

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Abstract

This article is a study of the application of the Questionnaire of Opinions on Science, Technology and Society (COCTS*) with a new methodology based on a multiple-response model, to achieve a more valid and meaningful assessment of attitudes regarding issues of science, technology & society (STS), in a sample of high school students. It presents the application of this methodology and its ability to evaluate more precisely, both qualitatively and quantitatively, the STS attitudes of students whose overall level is mediocre, since they are outstanding for their lesser adaptation, and their beliefs about science epistemology. It also shows the lack of equivalence between isolated statements used to assess attitudes and their methodological implications for research on attitudes. Finally, it suggests some implications of the results for teaching STS themes in the school.

Keywords: STS, STS attitude evaluation, STS opinions questionnaire, Multiple-Response Model, student attitudes toward science and technology.

Resumen

En este artículo se presenta un estudio sobre la aplicación del Cuestionario de Opiniones de Ciencia, Tecnología y Sociedad (COCTS) con una nueva metodología y un modelo de respuesta múltiple para lograr una evaluación más válida y significativa de las actitudes relativas a los temas de ciencia, tecnología y sociedad (CTS), de una muestra de estudiantes de bachillerato. Se expone la aplicación de esta metodología y su capacidad para evaluar de una manera más precisa, cualitativa y cuantitativamente, las actitudes CTS de los estudiantes, cuyo nivel global es mediocre, ya que sobresalen, por su menor

* For ease of reference, where the names of organizations have been translated from the Spanish, their acronyms have been retained as given in that language. In the case of international organizations which have commonly-used acronyms in English, those acronyms have been used.

adecuación, sus creencias sobre epistemología de la ciencia. Así mismo, se muestra la falta de equivalencia entre frases aisladas para evaluar las actitudes y sus consecuencias metodológicas para la investigación de actitudes. Por último, se proponen algunas implicaciones de los resultados para la educación de los temas cts en la escuela.

Palabras clave: CTS, evaluación de actitudes CTS, cuestionario de opiniones CTS, Modelo de Respuesta Múltiple, actitudes de los estudiantes hacia la ciencia y tecnología.

Introduction

In contemporary societies, steeped in science and technology (S & T), people manage scientific and technical knowledge that enables them to meet their daily needs, be they personal, professional, practical, cultural, recreational or for democratic participation. Science, Technology and Society (STS) means a field of academic study and research. In science education it represents an innovation in science teaching aimed at understanding science and technology in a social context that shows their connections with various fields: economic, historical, sociological, philosophical, environmental and cultural (Acevedo, 1996; Aikenhead, 1994a, Gonzalez-Garcia, Lopez-Cerezo, and Lujan, 1996, Vazquez, 1999).

STS education has multiple objectives and can be carried out in various ways, but today these all tend to converge on the goal of *scientific and technological literacy for all people*—essential in science education (Acevedo, 2004; Acevedo, Manassero and Vazquez, 2002, 2005, Acevedo Vasquez and Manassero, 2003). Although there is no unanimity among specialists when it comes to clarifying its meaning (Acevedo, Vazquez and Manassero, 2003, Martin Diaz, Julian Gutierrez,and Gomez-Crespo, 2005), it can be argued that literacy goes beyond the basic objectives. It promotes more training in procedures, and above all, in attitudes; that is, the greater interest and awareness towards the role of science and technology in today's world.

The goal of *science for everyone* aims to expand scientific and technological literacy to the entire population without restrictions, as opposed to the propedeutic and elitist nature of traditional science teaching. These objectives have important for curricular, methodological and evaluational implications, which are radically different from traditional science education. The scientific and technological literacy of all people requires teaching inclusive, not exclusive content; emphasis on learning procedures and attitudes; and the adoption of evaluation criteria consistent with it (Aikenhead, 1994b, 2003, 2004, Vázquez, Acevedo and Manassero, 2005).

In recent years, various international organizations and numerous experts in science education unite in having as their goal, students' achieving the development of more informed and appropriate concepts regarding science and technology, and their relations with society, as an essential part of scientific and technological literacy for everyone. However, empirical research shows repeatedly and consistently that students do not reach the desired understanding in STS

(Acevedo, 1992, 2001, Acevedo Vasquez, and Manassero, 2002; Acevedo, Vazquez, Manassero, and Acevedo, 2002; Ben-Chaim and Zoller, 1991; Fleming, 1987; Kang, Scharmann, and Noh, 2005; Lederman, 1992; Manassero and Vazquez, 1998, 2001, 2002; Manassero, Vázquez, and Acevedo, 2001, Ryan 1987, Ryan and Aikenhead, 1992; Solbes and Vilches, 1997, 2002, 2004, Vazquez and Manassero, 1996, Zoller, Donn, Wild, and Beckett, 1991, Zoller *et al*., 1990).

I. STS attitudes and beliefs

Unlike the traditional knowledge of S & T, in which dominates the cognitive component (knowledge, facts, concepts and principles), the STS issues add their own values and standards of science and technology, plus other social values. Thus, although there were cognitive elements in the basic STS beliefs, their nature is much more complex because it includes these other, more elusive aspects. This affective dimension of STS education is considered one of its most characteristic elements (Acevedo, 1996; Aikenhead, 1994b; Solomon, 1994; Vázquez, 1999).

Teaching STS issues assumes, therefore, the promotion of skills related to be learning of values and standards that go beyond the cognitive content; although this should also be maintained. STS teaching and learning requires a willingness to open oneself to the understanding of different positions on different issues, which involves emotional and affective components (coming out in favor of one position or another); and behavioral ones (intention to act in accordance with what one has chosen). These components are the core of the learning of values and norms unique to STS orientation in science education.

To describe this kind of affective concepts related to STS topics in the literature there are employed various terms, such as beliefs, opinions, attitudes, ideas, and so etc. In psychology, the concept of attitude takes into account the cognitive, affective and behavioral effects of these items. In a review of programs aimed at improving the concepts of the nature of science, Abd-El-Khalick and Lederman (2000) suggest that *implicit approaches* refer to these concepts as rules or attitudes, whereas *explicit approaches* basically consider improvement to be a cognitive result. Both approaches can be correct if one needs the concept of *attitude* as a personal psychological disposition that involves the evaluation, positive or negative, of an object, by explicit or implicit responses containing cognitive, affective and behavioral elements (Eagly and Chaiken, 1993). In sum, the concept of attitude, whose main component is the affective value of an object, which is also part of its knowledge, establishes better the type of knowledge specific to STS issues. Furthermore, the proposal to use the notion of attitude is in synchronization with the more general proposal to seek constructs developed in other research areas, particularly social psychology, as an answer by which to avoid serious methodological problems of validity and reliability that appear in the research on science teaching itself (Shrigley and Koballa, 1992).

II. STS assessment tools and methodologies

The difficulties arising from the methodological issues involved in assessing STS attitudes affect the validity and reliability of the instruments and methods applied, and consequently, the interpretation and significance of the results. Several review studies have shown significant methodological flaws in the numerous instruments developed in recent decades (Acevedo, Acevedo, Manassero and Vazquez, 2001, Gardner, 1996; Munby, 1997). Among the main defects identified are the following:

- The instruments and effectively reflect prejudices of their designers, so that the researchers' beliefs are implicitly imposed on participants by the choices offered (Lederman, 1992). Thus, the results end up attributing to participants, beliefs which are more a result of the instrument applied, than a faithful representation of their own views.
- The hypothesis of *immaculate perception*, which assumes that the researcher and the participant perceive and understand the text of a questionnaire in the same way (Aikenhead and Ryan, 1992; Aikenhead, Ryan, and Desautels, 1989, Lederman and O'Malley, 1990), so that the agreement or disagreement with a statement is always a result of the same reasons imagined by the designers of the instrument.
- Standardized instruments severely limit the ability to extract meaningful conclusions and evaluate changes in attitudes, since it is difficult to establish clearly what numerical score values signify an "appropriate" or "inappropriate" attitude, especially because of the low-level validity of the content (lack of correlation between what the instrument is intended to measure and what is actually measured) or because they violate the one-dimensional construct, necessary on any instrument for validating the metric results and corresponding interpretations (Aikenhead, 1988; Shrigley and Koballa, 1992).

Since the greater part of the research had been done with instruments using paper and pencil, these criticisms provoked a certain amount of precaution with regard to quantitative research, which coincided with a change of methodological paradigm toward softer, more relaxed qualitative methodologies (interviews, open questionnaires, case studies, etc.) Although qualitative methods are better suited to revealing the participants' thinking, they also introduce biases and can hide some key aspects of the research, in particular, the researcher's interpretations of the records obtained (Lederman, 1992).

Aikenhead (1988) addressed this problem. He compared the validity of various instruments (Likert scales, multiple-choice questionnaires closed, empirically-developed questionnaires and interviews) and concluded that the interviews provide a greater wealth of data but are time-consuming; thus, empirically-developed questionnaires based on open questions and previous interviews are a valuable third type of technique. They combine the advantages of the closed instruments, with the wealth of the interviews, save a great deal of application time, and can be applied to large samples.

Developed along these lines were the questionnaires Views on Science, Technology and Society (VOSTS) (Aikenhead and Ryan, 1989; Aikenhead, Ryan and Fleming, 1989), which has been used with students and teachers (Aikenhead and Ryan, 1992, Fleming 1987, 1988; Zoller, Donn, Wild, and Beckett, 1991a, b); and The Teacher's Belief about Science-Technology-Society (TBA-STS) (Rubba and Harkness, 1993; Rubba, Schoneweg and Harkness, 1996), used with teachers.

Based on a taxonomy of attitudes related to science and technology (Vazquez and Manassero, 1995) and following similar patterns, the questions used in these two instruments have been adapted to the Spanish cultural context. On that basis they built the Questionnaire of Opinions on Science, Technology and Society (COCTS) (Manassero and Vazquez, 1998; Manassero, Vazquez and Acevedo, 2001, 2003a), whose implementation has suggested new methodological guidelines for improving validity and reliability, such as:

- Exchanging a single-response model (MRU), which provides minimal information about each participant's thinking, for another of multiple choice (MRU), which allows using all the available information on each item.
- Creating new metrics, which permits one to extract from the multiple responses all the information they contain.
- Defining a standardized global attitudinal index, with an invariable metric value that reliably synthesizes the entire set of answers given.
- Classifying all the statements of the questionnaire in three categories, through an evaluation by a panel of specialist judges. This allows the application of a measure suitable for calculating attitude.

These methodological improvements allow quantitative applications such as inferential statistics and comparison of research groups in studying STS items; as well as advancing in techniques specific to qualitative research, such as is the case of personalized diagnostics (Acevedo, Acevedo, Manassero and Vazquez, 2001; Manassero and Vazquez, 1998; Manassero, Vázquez, and Acevedo, 2001, 2003a, 2003b, 2004; Vázquez, Acevedo, and Manassero, 2000, Vazquez and Manassero, 1999, Vázquez, Manassero, and Acevedo, 2005, 2006).

The purpose of the study described in this article was to evaluate the STS beliefs and attitudes of a group of high-school students through the COCTS and the new methodological procedures described. It shows the advantages and possibilities of the questionnaire and MRM applied, as well as the ability of both to assess students' STS beliefs and attitudes reliably and meaningfully. The methodology used was based on a quantitative perspective, but also allows for qualitative analysis.

III. Methodology

This section presents the sample of students participating in the study, the principle characteristics of the instrument used in the evaluation, and the procedure followed in the investigation.

3.1. Sample

Dictionary Participating in this study were 57 high school students (33 boys and 24 girls) enrolled in the elective course Science, Technology and Society, in three different groups, in two schools in Palma de Mallorca (Spain). Of these, 33 are majoring in Science and Technology, and 24, in Social Sciences and Humanities.

3.2. Instrument

Items used in this study are taken from the cocts, a bank of 100 STS items adapted and improved in their application methodology during several school years, as indicated in the preceding paragraphs.

All the COCTS items have the same multiple-choice format. They begin with a header of a few lines, in which is expressed a problem used to determine the person's attitude, followed by a list of statements that offer a range of different explanations with regard to the issue raised, together with three fixed options giving various reasons for not answering; for example: "I don't understand the question," "I don't know enough about the subject to select an option" and "None of the options really express my opinion" (see the text of an item in Table I).

Table I. Example of a COCTS item

10211 Defining what the technology is can be difficult because it can be used for many things. However, technology is PRINCIPALLY:											
For each one of the following statements, mark the scale number which best represents the level of agreement between your own opinion and the position shown in the statement.	**Level of Agreement**										Cat.*
	Low			**Me-dium**			**High**				
A	Very similar to science.	1	2	3	4	5	6	7	8	9	P
B	The application of finance.	1	2	3	4	5	6	7	8	9	N
C	New processes, instrument, machinery, applications, Equipment, computers, or practical apparatus for everyday use.	1	2	3	4	5	6	7	8	9	P
D	Robots, electronics, computers, communications systems, remote-controlled items, machines.	1	2	3	4	5	6	7	8	9	P
E	A technique for constructing things or a way of solving practical problems.	1	2	3	4	5	6	7	8	9	P
F	Inventing, designing, or trying out things (for example, artificial hearts, computers, and space vehicles).	1	2	3	4	5	6	7	8	9	P
G	Ideas and techniques for designing and making thing; for organizing workers, business people and consumers; and for the progress of the society.	1	2	3	4	5	6	7	8	9	A
H	Knowing how to make things (for example, instruments, machinery, apparatus).	1	2	3	4	5	6	7	8	9	P
If one or more of the following statements are applicable to the foregoing options, write the letter of the option beside it/them. 1. I don't understand. 2. I don't know enough about this topic to choose an option. 3. None of these options really fit my opinion.											

(*) The category is indicated by: A (appropriate), P (plausible) and N (*naïve*), for each option.

The multiple-choice format allows participants to express their points of views on a wide range of aspects of each topic, which may not appear in an open response, and in consequence, the attitude formed by the evaluation of the different aspects covered is quite rich and full.

The 28 items chosen for this study included 202 sentences, which should be evaluated by students, and represent the majority of the dimensions, topics and subtopics addressed by the COCTS (see Table II).

Table II. COCTS Items, indicated by their numerical identification code, applied in this study

Topics	Subtopics	Items
Definitions		
1 Science and technology	01. Science	10111
	02. Technology	10211
	04. Interdependence	10412, 10413
3. Triadic Influence	01. Interaction science/technology/society	30111
External sociology of science		
2. Society's influence on science and technology	04. Ethics	20411
	05. Educational institutions	20511
	06. Special-influence groups	20611
	08. General influence	20811, 20821
4. Influence of science and technology on society	01. Social responsibility	40111
	02. Social decisions	40211
	03. Social problems	40311*
	05. Financial welfare	40511*
	08. General influence	40811*, 40821*
5. Influence of in-school science education on society	01. Union of two cultures	50111*
	02. Social reinforcement	50211*
	03. Scholastic description of science	50311*
Internal sociology of science		
6. Characteristics of scientists	01. Motivations	60111
	05. Effects of gender	60511
7. Social construction of scientific knowledge	02. Scientific decisions	70211
8. Social construction of technology	01. Technological decisions	80131*
	02. Technological autonomy	80211*
Epistemology		
9. Nature of scientific knowledge	02. Scientific models	90211
	05. Hypotheses, theories and laws	90511
	06. Approach to research	90611
	10. Epistemological status	91011

(*) Items not applied on the post-test.

Each statement is identified by a code composed of a five-digit number (in the middle), and two letters that precede and follow that number. The middle number represents the different STS dimensions, topics and subtopics and corresponds to the code specification in the original VOSTS Table. The letter preceding the number (A, P or R) represents the category (appropriate, plausible or *naïve*) assigned to the statement, as rated by a judges' scaling method. The final letter represents the relative position of the sentence within each item, listed alphabetically (A, B, C, etc.)

3.3. Procedure

The teachers of the high school STS subject applied selected items in their classes as part of a classroom activity designed to explore students' attitudes and beliefs about STS topics. The response method applied to the questions was adjusted to a MRM, in which all the statements that made up each item assessed the degree of agreement/disagreement on a nine-point scale (Manassero and Vazquez, 1998; Vazquez Manassero, 1999).

Each direct assessment was then converted into attitudinal indices (Table III), as classified in three categories (appropriate, plausible, and *naïve*) previously assigned to each statement by a panel of expert judges (Acevedo, Acevedo, Manassero, and Vazquez, 2001; Manassero, Vazquez, and Acevedo, 2001; Vazquez, Acevedo, and Manassero, 2000, Vazquez, Manassero, and Acevedo, 2005, 2006).

Table III. Multiple-response model (MRM) for a COCTS item
(Signified by the direct scores ofagreement/disagreement
with each alternative statement, assignment of points on the evaluation
scale, and calculation procedures for the attitudinal indices based on the direct scores)

Cate-gories	**No. of state-ments**	**Evaluation scale: transformation of the direct scores**									**Direct attitudinal scores**			**Attitudinal indices by category**		
Direct scale		**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**						
Level of agreement		Total	Almost total	High	Partial high	Partial	Partial low	Low	Nearly null	Null	Max.	Formula	Min.	Max.	Formula	Mín.
Appro-priate	Na	4	3	2	1	0	-1	-2	-3	-4	+4Na	Σaj	-4Na	+1	Ia =Σ aj / 4Na	-1
Plausible	Np	-2	-1	0	1	2	1	0	-1	-2	+2Np	Σpj	-2Np	+1	Ip =Σ pj / 2Np	-1
Naïve	Nn	-4	-3	-2	-1	0	1	2	3	4	+4Nn	Σnj	-4Nn	+1	In =Σ nj / 4Nn	-1
Total	N										Index of global attitude			1	I = (Ia+Ip+In)/3	-1

aj: Direct evaluation score for the appropriate statement j.
pj: Direct evaluation score for the plausible statement j.
nj: Direct evaluation score for the *naïve* statement j.
Na, Np, Nn: Number of statements belonging to each of the categories "appropriate", "plausible or "*naïve*".
Σ: Sum of direct scores based on j = 1 a j = Na (j = Np o j = Nn) for the set of statements belonging to each of the categories "appropriate", "plausible or "*naïve*".

The MRM applied allowed us to obtain standardized attitudinal indices (-1, +1) for each sentence, according to the category assigned. Thus, the "appropriate" sentences were valued higher as they approached 9; the *naïve* ones as they got closer to 1; and the plausible ones (which included aspects appropriate in part) as they approached 5 (the mid-value of the scale).

Based on the indices of the statements of an item, three new indices could be calculated for each of the three sentence categories: *appropiate, plausible* and *naïve*, as an average of the previous indices for the statements in each category.

Finally, as an overall indicator of each person's attitude toward the topic of an item, a weighted attitudinal index could be calculated (average of the indices for all three categories), following the procedure outlined in Table III.

IV. Results

Description of the results will proceed from the most comprehensive quantitative aspects of the group (statistical parameters descriptive of the sample for all the items applied), to the most specific and qualitative aspects (individual diagnosis, sentence scores, alternative beliefs, etc.)

To analyze the results we calculated the average index of each statement on the questionnaire for the entire sample. Based on this index we were able to calculate a global average and average overall indices for each category (*appropiate, plausible and naïve*) for the whole group, the indices of each category for each item, and the weighted index for each item, as well as the weighted average indices of the 28 items applied.

4.1. Students' Attitudes

The parameters used to make a first approach to the statistical description are the key measurements of the attitudinal indices obtained from the student's responses, such as the arithmetic mean and the standard deviation of the means in each of the 202 sentences evaluated for the entire sample.

Altogether, analysis of the distribution of the means for each of the statements indicates a slight bias towards slightly positive attitude values for the whole sample, since the overall average mean scores for the statements is positive, but close to zero (+ 0.067 points and D.T. = 0.229). That is, there was obtained a very low overall value for students' positive STS attitudes.

Although in principle this was an expected outcome, such a small positive value suggests that students' overall attitudes were unsatisfactory. The distribution of mean scores on each sentence for the entire sample ranges from a maximum value (+0.741 in the *naïve* statement I1011I) to a minimum value of -0.417 (in the *naïve* statement 10412B). As these results show, the distribution of values is skewed positively, since the high values for the positive scores were more extreme than the low values for the negative scores (Table IV).

Table IV. Statistical parameters of the distribution of average standardized attitudinal indices (-1, +1) for the sample's answers to the set of COCTS items

	Average scores[o]	**Appropriate[a]**	**Plausible[a]**	***Naive*[a]**	**Overall weighted index ***
Median	0.067	0.231	0.063	-0.025	0.080
Est dv.	0.229	0.166	0.168	0.279	0.101
Maximum	0.741	0.557	0.500	0.741	0.251
Minimum	-0.417	-0.214	-0.391	-0.417	-0.118
Range	1.157	0.771	0.891	1.157	0.368

(o): Individual median score averages for each statement.
(a): Average of the medians for the standardized attitudinal indices for the appropriate, plausible, and *naïve* statements, respectively, of each student.
(*): Average of the medians for the three above (appropriate, plausible, *naïve*).

4.2. General parameters of distribution

To get a better picture of student' attitudes it was necessary to show additional details regarding the distribution of median indices for statements and items. A first step toward this was to analyze the global parameters descriptive of the group (average indices) for each of the categories of appropriate, plausible and *naïve* statements.

These average indices showed notable differences between the three categories. Indeed, the indices for the appropriate statements were positive, and were the highest; those of the plausible were slightly positive; and the *naïve*, slightly negative. Thus, the contribution of the three categories to the global attitudinal index was different. While the appropriate statements contributed in a moderately positive manner, the *naïve* and plausible sentences did so to a lesser extent, although in the opposite direction. On the other hand, the participating students seemed to find it much easier to identify the plausible sentences than the plausible, and even easier still than the *naïve*.

"In contrast, the amplitudinal range and standard deviation of the scores for each category, showed an order opposite to that above, with the *naïve* statements ranked highest, and the appropriate ones, lowest. This pattern of overall variation between categories suggests that students' adherence to the more appropriate positions of the STS items seemed to be a little easier than that of *naïve* and plausible sentences.

The above results demonstrate how to what point the attitude measurement could change significantly depending on the category of the statement applied. This issue has important methodological implications for the validity of attitude-evaluation instruments, and will be addressed in the discussion section.

4.3. Strengths and weaknesses of STS attitudes

It is possible to perform qualitative studies of specific questions by analyzing the mean indices of each sentence of an item. These provide direct information about the overall attitude of the sample (or of each person) regarding the belief expressed in each sentence. The highest and lowest attitudinal scores for sentences are indicators of students' strongest and weakest attitudes, respectively.

High scores indicate beliefs consistent with a proper understanding of science and technology, from a current perspective of the philosophy, history and sociology of science, while low scores represent the most dissonant ideas (see Table V).

Table V. Statements whose median index is very high,
and which represent correct attitudes on the part of the students

Statement	Index	Text of the statement
A10111B	0.478	A body of knowledge, such as principles laws and theories which explain the world surrounding us (matter, energy and life).
A10413D	0.329	Technological advances lead to progress in science.
A10413F	0.353	Technology provides tools and techniques for science.
A20821C	0.386	Scientists are members of society. When society shows more interest on a topic, scientists are more willing to study it.
A30111E	0.458	[Diagram with equal interaction science, technology, and society, see Annex 1.]
A30111F	0.315	[Diagram with interaction science, technology, and society weaker between science and society, see Annex 2.]
A40111D	0.402	Scientists are not worried, but it is possible they don't know all the long-term effects of their discoveries.
A40111E	0.326	Scientists are not worried, but they have little control over the way their discoveries may be misused.
A40211D	0.491	It should be a shared decision. The opinions of scientists and engineers, other specialists and informed citizens should be taken into account in the decisions that affect our society.
A40311B	0.314	Because scientists cannot predict the long-term effects of new developments, in spite of careful planning and testing. We must take the risk.
A40511B	0.394	Because more science and technology would make our country less dependent on other countries. We ourselves could produce things.
A40811C	0.356	Technology is part of all the aspects of our lives, from birth to death.
A50111E	0.557	There are not only these two types of people. There are possible as many kinds of people as individual preferences, including those that understand both—science and letters.
A60511G	0.371	Because whatever difference in their discoveries is due to individual differences. Such differences have nothing to do with whether one is a man or a woman.
A80131B	0.297	The decision depends on more than just the advantages or disadvantages of technology. It depends on how will it functions, on its cost and its efficiency.
I10111I	0.741	It is impossible to define science.

I10412A	0.569	Science doesn't have too much influence on technology.
I10413A	0.373	Technology has little influence on science.
I20811A	0.397	Society has little influence on technology.
I20821A	0.491	Society has little influence on science.
I30111G	0.375	Mutual interaction between science, technology and society (graphic)
I40811A	0.618	Technology has little influence on society.
I40821A	0.559	Science has little influence on society.
I40821B	0.373	Science has a direct influence only on members of society who are interested in science.
I60511I	0.387	Men make somewhat different discoveries, because men are better at science than women are.
I60511J	0.469	Women would probably make better discoveries than men, because women are generally better than men in some things like instinct and memory.
P70211C	0.482	Because different scientists interpret facts and their meaning in different ways. This happens because of different scientific theories. NOT because of moral values or personal motivations.
P70211D	0.500	Principally because of different or incomplete facts, but partly because of different moral values, opinions, or personal motivations.
P90211G	0.333	Because these models should be well-informed ideas or conjectures, since the real object cannot be seen.

Sentences with the highest scores represent the beliefs of those students who are more in accord with an appropriate understanding of science and technology. The five sentences with the highest positive scores, that meet stringent criteria for superseding the sample mean by more than two standard deviations are mostly *naïve* (shaded in Table V). Among them are the following four beliefs:

- Science cannot be defined (I10111I).
- Science does not have much influence on technology (I10412A).
- Technology is does not have very much influence on society (I40811A).
- Science does not have very much influence on society (I40821A).

All these are easily-accepted claims in a developed society, where science and technology are constantly present in everyday life and in the society (e.g., in social communications media and in advertising), and therefore do not need an excessive amount of communications and technological knowledge for their recognition. The appropriate statement (A50111E) which states that "there are not just two types of people (scientists and non-scientists), since as there can be as many kinds of people as there are individual preferences, including those who understand both science and letters;" since this also seems to be a fairly common idea in contemporary society, the high value of the index is not too surprising.

If there is applied a less demanding criterion that exceeds the highest scores from the sample mean on more than one standard deviation, 29 sentences are obtained (Table V). Among them there are 15 appropriate, 11 *naïve* and only 3 plausible statements, so that most of the participating students' best beliefs correspond to statements classified as *appropriate* by the judges. This analysis reconfirms the idea that different statements are not equivalent for the diagnosis of attitudes: the *appropriate* and *naïve* statements are much better than the plausible ones identified by students.

At the other extreme, the sentences with the lowest scores represent students' beliefs less in accord with a good understanding of science and technology. They could be interpreted as alternative ideas about the nature of science, with respect to current knowledge about philosophy, history and the sociology of science.

In this case, one can also use two identification criteria. If there is applied the less stringent criterion that scores are lower in more than one standard deviation from the sample's mean, 40 statements are obtained. These appear in Table VI. Of these, 28 are *naïve* sentences, 11 are plausible and only one is appropriate.

Table VI. Statements whose mean index is very low, and which represent incorrect attitudes on the part of the students

Item	Index	Statements
A50311F	-0.214	Nothing, neither TV programs nor science classes, gives exact images of science. TV programs exaggerate, distort, and simplify too much. Science classes just give notes, problems and details that have nothing to do with daily life.
I10211B	-0.276	Application of science.
I10412B	-0.417	Technology is applied science.
I10412G	-0.371	Technology is the application of science for the improvement of life.
I10413G	-0.359	Technology is the application of science for the improvement of life.
I20411F	-0.250	Because research continues in spite of confrontations between scientists and certain religious or cultural groups (for example, between those who believe in evolution and those who believe creation).
I20411G	-0.273	Because scientists will investigate topics that are important to science and to themselves, in spite of cultural or ethical opinions.
I20511E	-0.186	Because it will not work. Some people don't like science. If they're forced to study it, it will be a waste of time and it will drive them away from science.
I20511F	-0.185	Because not all students can understand science, even though it would help them in their lives.
I20511H	-0.190	Because it's not good for somebody else to decide whether a student ought to choose more sciences.
I20821B	-0.245	The social demand for understanding nature stimulates the accumulation of scientific knowledge.
I40111B	-0.291	The majority of scientists are worried about the possible detrimental effects of their discoveries, because the object of science is to make our world a better place to live in. For that reason, scientists test their discoveries to make sure no harmful effects will occur.
I40211A	-0.241	Because they have the training and the data to give them a better understanding of the topic.
I40211B	-0.350	Because they have the knowledge, and they can make better decisions than government bureaucrats or private enterprises, who have their own special interests.
I40811B	-0.268	Because they have the training and the data to give them a better understanding of the topic.
I40821C	-0.173	Science is available for the use and benefit of everyone.
I50211B	-0.196	Because they may not have the ability or the talent to understand science. Studying more science will not give them that ability.
I50211C	-0.211	Because they may not be interested in science. Studying more science will not change their level of interest.
I60111G	-0.347	Discovering new ideas or inventing things for the benefit of society. (for example, medical remedies, solutions for pollution, etc.)
I80131A	-0.264	The decision to use a new technology depends principally on its benefits for society, because if there are too many disadvantages, society will not accept it, and that will hold back its later development.
I90211B	-0.179	Because there are many scientific proofs which demonstrate that they are true.

I90211C	-0.198	Because they're true for life. Their object is to show us reality or teach us something about it.
I90511B	-0.366	Because a hypothesis is proved with experiments. If proofs exist to support it, then it is a theory. After a theory has been proved many times and seems to be essentially correct, that is enough for it to become a law.
I90511C	-0.214	Because it is a logical way to develop scientific ideas.
I90611D	-0.250	To obtain facts, theories or hypotheses efficiently.
I90611E	-0.207	To test/prove again and again, demonstrating that something is true or false in a valid fashion.
I90611F	-0.304	To postulate a theory, and afterwards create an experiment to prove it.
I91011B	-0.310	Because laws, hypotheses and theories are experiments are based on experimental facts.
I91011F	-0.183	It depends on each case; the laws are discovered and the theories are invented.
P10211A	-0.241	Very similar to science.
P10412C	-0.184	Advances in science lead to new technologies.
P40511A	-0.241	Because science and technology bring about greater efficiency, productivity and progress.
P40811E	-0.170	Technology provides society with the means to improve or destroy itself, depending on how it is used.
P40821G	-0.167	Science influences society through technology.
P50211G	-0.202	Because science classes have nothing to do with consumers or with the real world. For example, photosynthesis, atoms and density do not help me make better decisions as a consumer.
P60511A	-0.391	Because any good scientist can make the same discovery as any other good scientist.
P60511B	-0.344	Because men scientists and women scientists have the same training.
P60511C	-0.234	Because after all, men and women are equally intelligent.
P60511D	-0.167	Because men and women are the same with regard to what they want to discover in science.
P60511F	-0.339	Because we're all the same, no matter how much work we do.

Note: The criterion used has been to achieve a lower index in more than one standard deviation from the samples' mean (the only statement whose index is more than two standard deviations from the mean of the sample, appear shaded).

Only one sentence meets the most demanding criterion: that the score be lower than the sample mean in more than two standard deviations. This sentence corresponds to the familiar *naïve* belief that technology is applied science, which appears formulated in a slightly different manner in three other statements with significant negative indices.

Among other alternatives there are several other *naïve* beliefs about the relationship between science, technology and society, such as that scientific research continues regardless of cultural or ethical views, and regardless of the clashes between scientists and religious or cultural groups, or on the other hand, that the social demand for understanding nature stimulates the accumulation of scientific knowledge.

A tendency toward scientism appears when it is admitted in a *naïve* manner that science consists in "discovering new ideas" or "inventing things for the benefit of society." There is also an over-reliance on scientists when one considers that most of them are worried about the possible adverse effects of their discoveries, have the training and information that give them better understanding of the issues, or have the knowledge and do not act out of personal interest.

Other outstanding *naïve* beliefs are that science is available for the use and benefit of everyone; but there should not be more science studied in school, because that would not give students the ability to understand it better or improve their interest in it. Furthermore, it is believed that one cannot force people to study science because some people do not like it; that not everyone can understand it; and that others should not decide for students what they have to study.

The most *naïve* ideas concerning the epistemology of science, which can be seen in Table VI, also show the credulity of students in believing in the absolute and cumulative character of scientific knowledge, a certain unsophisticated realism imbued with more conviction regarding discovery than concerning the invention and construction of scientific knowledge, as well as belief in the ability of experiments to test hypotheses, in theories as mature laws and in the existence of a universal scientific method.

All in all, students in this study show a collection of *naïve* STS beliefs, which include some that are consistent with the results of previous research on the nature of science, and others that provide new profiles of students' STS.

4.4. Diagnosis of attitudes relating to an STS item

Based on the standardized attitude indices obtained for each statement, there can be calculated for each item a global index, which represents the attitude toward the issue raised therein. This calculation can be made by using two different procedures. The first calculates the arithmetic mean of the attitudinal indices of all the statements making up each item (overall mean attitude index.) The second, a little more sophisticated, consists in first calculating the averages for the set of statements by categories (appropriate, plausible and *naïve*) of the item separately, so as to obtain three indices (one for each category). Then one calculates the average of these (weighted global attitudinal index), following the procedure described on the right side of Table III. For various reasons, mostly due to better weighting of the various categories, this second method is the one applied despite its greater complexity (Manassero, Vázquez, and Acevedo, 2004; Vázquez, Manassero, and Acevedo, 2005).

Similarly, one can repeat the qualitative analysis for each individual sentence in order to identify the most powerful aspect and the weakest, and for each of the categories, by analyzing the mean indices of these, for the various items. As an example, in Table VII there is a summary of the calculation of the indices for three items, done using both methods: one with a large number of plausible sentences (10211), another with a large number of *naïve* sentences (90,611) and a third more balanced as to the types of sentences (91011). The indices of the three categories assume an approach to the overall thinking of the sample (or that of each student); this highlights the strengths and weaknesses relative to the more *naïve* or more appropriate beliefs about a question.

Table VII. Index values for the three Items

Median scores[o]	Appropriate[a]	Plausible[a]	*Naive*[a]	Weighted global index *	Statement	Media
Item	10211					
					P10211A	-0.241
					I10211B	-0.276
					P10211C	0.088
					P10211D	0.152
					P10211E	0.018
					P10211F	0.145
					A10211G	0.211
0.002	0.211	0.014	-0.276	-0.017	P10211H	-0.079
Item	90611					
					I90611A	0.121
					I90611B	-0.043
					I90611C	0.071
					I90611D	-0.250
					I90611E	-0.207
					I90611F	-0.304
					P90611G	0.125
					P90611H	0.161
					I90611I	-0.028
-0.038	-0.027	0.143	-0.091	0.008	A90611J	-0.027
Item	91011					
					I91011A	-0.107
					I91011B	-0.310
					P91011C	0.185
					P91011D	0.071
					A91011E	0.087
-0.043	0.087	0.128	-0.200	0.005	I91011F	-0.183

(o): Aunrosal2011Average of the individual median scores on the statements.
(a): Median averages of the standardized attitudinal indices for the appropriate, plausible and *naïve* statements, respectively, for each student.
(*): Median averages for the three above (appropriate, plausible, *naïve*).

The results of the global index for the items listed are similar (around zero), but when the scores of the three categories are analyzed, the following aspects stand out:

- The first item (10211) repeats the general pattern of the overall sample, with a moderately low index for the appropriate sentences, an index of close to zero for the plausible ones, and a negative index for *naïve* sentences. The strongest aspect of this item is the recognition of appropriate ideas, while the weakest the inadequate identification of *naïve* statements.
- The index for the scientific method (90611) has its strength in identifying plausible sentences, but fails to recognize appropriate and *naïve* ideas.
- By contrast, the attitude toward the nature of discovery or invention of scientific theories (91011) has the strongest point in the index of plausible sentences, while the weakest is that of the *naïve* statements.

If this analysis based on quantitative indices is extended to the individual sentences also, new results and details of assessments of attitudes can be obtained. For example, in the category plausible of Item 10211, although the average is almost zero, there are differences between the scores of the various statements of this type, some clearly positive and some clearly negative. So this analysis—a bit more thorough—can come even closer to the achievements and shortcomings of the group (or persons considered individually.)

From a teaching perspective, there is an obvious educational value for this type of evaluation and a qualitative analysis based on the quantitative data obtained. Thus, for the above items, the planning of teaching requires activities of a different sort depending on the strengths and weaknesses. In this case, the most common weaknesses relate to the *naïve* beliefs; in others, it might require a methodology of conflict between good and *naïve* beliefs.

4.5. Diagnosis of attitudes toward an issue

In addition to qualitative and quantitative microanalyses of each issue, such as those outlined above, it is also possible to conduct a larger study focused on a specific STS dimension (e.g., attitudes toward the influence of society on S & T) by analyzing a set of items belonging to the same dimension. Here are some results taken from the responses that participating students gave to the questions in each dimension (Table VIII).

Table VIII. Average indices for each of the COCTS questions

Questions	Average scores[o]	Appropriate[a]	Plausible[a]	*Naive*[a]	Overall weighted index *
C10111	0.182	0.224	0.045	0.482	0.251
C10211	0.002	0.211	0.014	-0.276	-0.017
C10412	-0.015		0.028	-0.073	-0.022
C10413	0.168	0.318	0.104	0.007	0.143
C30111	0.152	0.386	0.000	0.058	0.148
C20411	-0.056		0.026	-0.261	-0.118
C20511	-0.040	0.182	-0.049	-0.088	0.015
C20611	0.086	0.227	0.093	-0.004	0.105
C20811	0.166	0.206	0.112	0.397	0.238
C20821	0.143	0.245	0.011	0.123	0.126
C40111	0.113	0.364	0.058	-0.056	0.122
C40211	-0.028	0.206	-0.012	-0.295	-0.034
C40311	0.152	0.314	0.164	0.043	0.174
C40511	0.185	0.312	-0.241	0.231	0.101
C40811	0.123	0.250	0.033	0.175	0.153
C40821	0.171	0.000	0.110	0.253	0.121
C50111	0.114	0.557	0.006	-0.005	0.186
C50211	-0.037	0.168	-0.065	-0.074	0.010
C50311	0.049	-0.214	0.123	-0.134	-0.075
C60111	0.048	0.183	0.198	-0.191	0.063
C60511	-0.031	0.371	-0.219	0.428	0.193
C70211	0.178	0.213	0.322	-0.127	0.136
C80131	0.148	0.252	0.250	-0.264	0.079
C80211	0.106	0.074	0.153	-0.047	0.060
C90211	0.075	0.146	0.292	-0.117	0.107
C90511	-0.133	-0.045		-0.155	-0.100
C90611	-0.038	-0.027	0.143	-0.091	0.008
C91011	-0.043	0.087	0.128	-0.200	0.005
Average	0.069	0.200	0.068	-0.009	0.078
Standard Dev.	0.094	0.158	0.129	0.213	0.098

(º): Average for the individual median scores for each statement.
(ª): Average for the medians of the standardized attitudinal indices for the appropriate, plausible and *naïve* statements, respectively, for each student.
(*):Median averages for the three above (appropriate, plausible, *naïve*).

a) Definitions of science and technology

The dimension *Definitions of Science and Technology* was evaluated by four questions on the definition of science (10111), the definition of technology (10211), and the mutual dependence between science and technology (10412, 10413). To complete it, there was also included in this dimension a question concerning the interaction between science, technology and society (30111).

All in all, attitudes toward this dimension were low, but positive. The more positive overall attitudes toward the questions (about +0.20) were obtained regarding the definition of science; the influence of technology on science; and the interaction between science, technology and society. In contrast, the lowest overall attitudes (around zero) were obtained for the definition of technology, and the influence of science on technology.

The general profile of the attitudinal indices by category showed some similarities and some differences. The similarities are given in the scores for the appropriate statements, which were more positive in all cases (indices between +0.2 and +0.4), and the scores for the plausible sentences, which were grouped at values close to zero (between 0 and +0.1). The differences appear in the indices for *naïve* statements, notable for their wide dispersion of positive and negative values, ranging from a very positive value in the case of the definition of science (near +0.5) to a very negative value for the definition of technology (close to -0.3).

The profiles of variation between categories declined in three items, going from the appropriate statements to the *naïve*, passing through the plausible (intermediate), while the profiles of the other two items showed a variation in V (appropriate: high; plausible minimum ; *naïve*: high). All in all, the overall profile of this dimension showed the highest rates in the appropriate statements, intermediate (near zero) for the plausible and widely dispersed in the *naïve.*

b) External Sociology of Science

The dimension *External Sociology of Science* was the most extensive in the number of subjects represented. It comprises two subdimensions: the "influence of society on science and technology" and the "Influence of science and technology on society."

Included in the first subdimension were ethical issues (20411), educational institutions (20,511), special interest groups (20611) and the mutual influence between society and science and technology (20811, 20821). Overall attitudes varied widely, depending on the topic addressed in the questions. The question with the highest score (greater than +0.20) was that related to the general influence of society on technology (20811). Those for special interest groups (20611) and the general influence of society on science (20821) were moderately positive. The attitudinal index was practically null on the question related to studying more science and technology in educational institutions (20511), and moderately negative in the question about the influence of ethical beliefs on science (20411).

Index by categories showed a profile similar to the previous dimension (definitions of science and technology): the more positive indices appeared in the evaluation of appropriate sentences (about +0.2), followed by plausible sentences, in this case with a greater dispersion (grouped around values close to zero, from a slightly negative value +0.1), and widely dispersed values in the indices of *naïve* statements, which ran from a very positive value for the *naïve* statements regarding the influence of society on science (+0.4), to very negative for *naïve* statements about the influence of ethical beliefs (about -0.3).

Three profiles of variation decreased from the appropriate statements to the *naïve*, passing through to the plausible (intermediate), while two others showed a variation in V (appropriate: high; plausible minimum, *naïve* high). In summary, this subdimension showed the highest rates in the category appropriate, close to zero in the plausible, and widely dispersed in the *naïve*.

In the second sub-dimension were included issues of social responsibility (40111), social decisions (40211), social problems (40311), economic welfare (40511) and the general influence of science and technology on society (40811, 40821).

The indices of global attitudes (mean and weighted index of the items) for these questions were very similar and moderately positive (between +0.1 and +0.2), except for the question concerning social decisions (slightly negative). The indices of the three categories showed scores minimally grouped and having great variation between the different items within each category. In the case of the appropriate statements, scores were positive for all questions except 40821 (index zero), while in the *naïve* and plausible, they were both positive and negative.

The variation across the three categories showed a dominant profile of decline in half the items (40111, 40211 and 40311) from the category appropriate (most positive) to the *naïve* (more negative or less positive) with an intermediate position for the category plausible. One item (40821) showed an inverse profile, rising from the category appropriate (least positive) to the *naïve* (most positive). The other two items (40511 and 40811) had a profile in V (high in the appropriate statements, minimum in the plausible, and high in the *naïve*).

The more positive indices appeared in the assessment of the appropriate sentences (between 0 and +0.4), followed by the plausible sentences (between +0.2 and -0.2), and were more scattered in the *naïve* statements, going from a clearly positive value at times (greater than +0.2), to a quite negative value on the issue of making social decisions (-0.3).

In summary, this subdimension showed the highest rates in the category appropriate, close to zero in the plausible, and widely dispersed in the *naïve*, but with wide variation in scores between the different items within each category.

As a further aspect of the *influence of science and technology* on society, there were also applied some specific questions related to the influence of in-school science on society, such as its contribution to the unification between scientific and humanistic culture (50111); the usefulness of in-school science (50211) and the scholastic description of science (50311). The indices of global attitudes (mean and weighted) for these items was very low, especially for the last two, and different from each other (positive, almost null to slightly negative.) The variation across the three categories showed profiles very irregular and different from those described above.

The indices of the items in the three categories showed great diversity. In the case of the appropriate statements, scores ranged from a very positive maximum (+0.5) and a quite negative minimum (-0.2); in the *naïve* all were negative (between 0 and -0.1), and the plausible ranged between positive and negative values close to zero.

In brief, the issue of in-school science's influence on society showed rates close to zero in most cases, and an irregular variation in the scores for the different items, resulting in relatively lower attitudes on the whole.

c) Internal sociology of science

The internal *sociology of science* included two items relating to the characteristics of scientists, such as their motivations for doing research (60111), and the effects of gender on science (60511). It also included an item related to the social construction of scientific knowledge, having to do with the decisions made by scientists (70211), and two pertaining to the social construction of technology, which referred to technological choices (80131) and the autonomy of technology (80211).

The results for this dimension presented a clear difference between the item related to the effect of gender on science (60511) and the others, for which reason it will be treated separately. The gender item presented the only negative attitude (-0.03) of this dimension as a direct mean of the sentences, and at the same time, the most positive (+0.20) as a weighted index. Indices by categories show a V variation (high in the appropriate statements (maximum for the dimension); minimum in the plausible (negative); and high in the *naïve* (also the maximum of the dimension).

The rest of the items of this dimension presented global parameters similar to those observed; but with a new profile of variation among the three categories. Global attitudinal indices, both mean and weighted averages, were grouped in a moderately positive band below +0.20.

The profile of the indices under the three categories showed a similar positive score for the appropriate and plausible statements, followed by a sharp drop to a negative minimum for *naïve* sentences.

In summary, the dominant profile of the attitudes in this dimension (with the exception of the gender-related) showed similar indices (higher and positive) in the categories appropriate and plausible, and a negative score in the *naïve* categories.

d) Epistemology

The dimension *Epistemology*, also called (in reductionist mode) "The Nature of Science" by many authors in the bibliography, contained many essential issues concerning the nature of scientific knowledge. It included topics relating to the nature of scientific models (90211), status and relationships between hypotheses, theories and scientific laws (90511), the approach to scientific methodology (90611) and the epistemological status of scientific knowledge (91011).

The results of this dimension presented the students' clearest insufficiencies, since the overall mean indices are the lowest, and are distributed around zero. The item dealing with scientific models has the most positive overall index of this dimension, although it is quite low (+0.10); and the one addressing the status and relationships between hypotheses, laws and theories presented the most negative overall index (-0.10). Indices by categories show an approximately inverted V variation, somewhat asymmetric (low in the appropriate statements, highest in the plausible, and low in the *naïve*).

In a word, this dimension shows positive and negative indices that are quite low, around zero, higher and more positive in the category of plausible sentences, and lower and negative in the *naïve* statements.

The overall indices of the various Items of epistemology suggested that the attitudes were based on the specific aspect addressed in each case. Thus, while in Item 90211 (epistemology of scientific models) the score was moderately positive, in 90511 (status and relationships between hypotheses, laws and theories) it was negative. The other two items, 90611 (nature of the scientific method), and 91011 (status of scientific knowledge) had intermediate indices.

Indices by categories also showed strengths and weaknesses in each issue, which could be analyzed according to the schemas already mentioned. Items 90211 and 91011 had indices in different categories with a negative charge on the *naïve* statements, and a positive on the appropriate and plausible. However, issue 90611 had negative indices in the categories of appropriate and *naïve* statements, while it had positive ones for the plausible sentences. All in all, the methodology used to assess the overall attitude in every STS dimension allowed us to diagnose the strengths and weaknesses, as already shown in previous sections. This will be completed in later analyses.

4.6. Diagnosis of individual attitudes

Quantification of the responses through the use of various attitudinal indices also allows personalized diagnoses, typical of qualitative research. The individual diagnosis can be made from two different levels:

- Relative, which consists in the evaluation of a person's attitude by other members of the group. The general reference could be the average of the whole group (in small samples, the person being compared should be excluded to improve reliability).
- Absolute, which is the individual attitude regarding the profile determined by the category which judges assign to sentences, i.e. the attitudinal score itself. The reference here is the maximum suitability score for each sentence, represented by the optimal attitude profile (set to the value +1 for all statements and items).

Taken as a whole, the index values of the group are distributed in all the statements along the whole range of attitudinal indices from the maximum rates (+1) to the minimum (-1), covering all the topological space of scores on all the items. This plurality of beliefs emphasizes the great diversity of the group's individual attitudes, which may indicate some confusion and lack of training in the area evaluated (Figure 1).

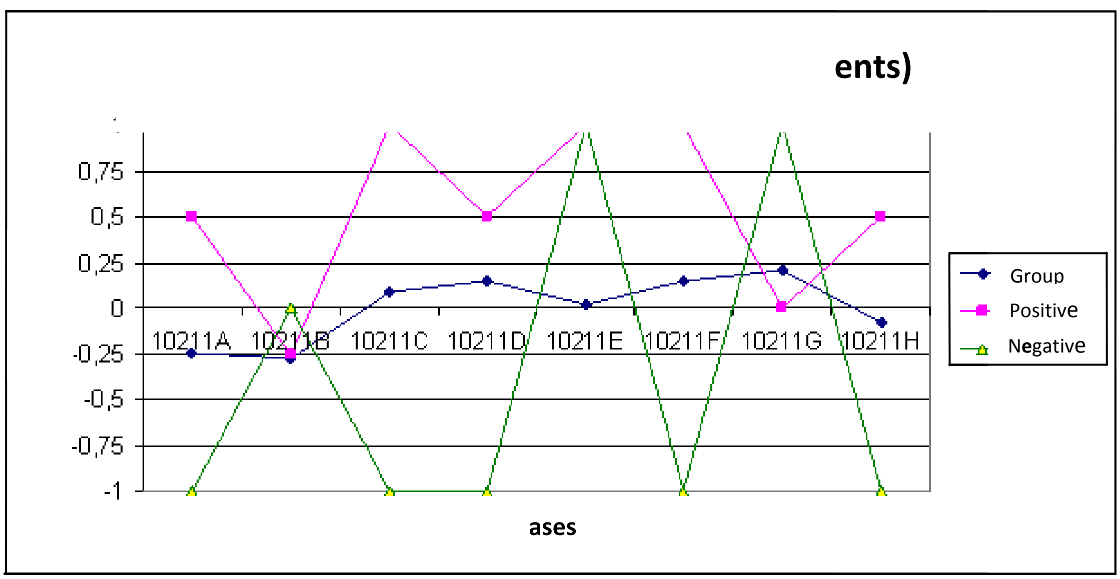

Figure 1. Comparison of the attitudinal profiles of the statements of Item10211 (definition of technology), for a student with a very positive attitude and another with a very negative attitude (as a reference, there is also shown the group's attitudinal average.

For example, as related to the question raised by the definition of technology (10211), Figure 1 depicts three attitudinal profiles belonging to the total group average and to the responses of two students who have extreme attitudinal scores on this issue, i.e., a very good attitude (highest mean attitudinal index) and a very poor one (very low mean attitudinal index). Similarly, in order to facilitate understanding, it could represent any other individual attitudinal profile not included in the figure.

Logically, the profile of the person with low attitude exhibits indices with a minimum evaluation level in many sentences, with the notable exception of sentences E and G, where the individual obtained a maximum evaluation (in the last, it is even superior to the score of the other student, who had a good attitude). The profile of the person with the better attitude is less homogeneous than the previous one, because the indices of the different statements take very different values, although none reached the minimum value.

These two examples of individual evaluation show, simultaneously, the complexity and wealth of the attitudes towards STS issues, since one person may obtain opposite scores on the sentences. At the same time, Figure 1 demonstrates once more the methodological problem of the ambiguous value an attitudinal assessment can have based on a single sentence. If a student with a negative attitude were evaluated only by her* response to the statement E (or G) she would get a maximum attitude, and vice versa, if a student with the best attitude were evaluated only for her response to the statement B, she would get a negative attitude.

V. Discussion and conclusions

Previous works have discussed the similarities and differences between the terms attitude, belief and opinion, all closely related, to refer to students' ideas on STS (Manassero, Vazquez and Acevedo, 2001, 2004, Vazquez, Manassero and Acevedo, 2005, 2006). The most fitting concept with which to encompass all the properties observed and described for students' STS opinions is that of *attitude*, which that includes all three: knowledge, feelings and behaviors. However, it should be noted as well, that beliefs would be the building blocks of attitudes (Eagly and Chaiken, 1993), an idea consistent with the decision to make operative the attitude toward a STS topic, using the standard attitudinal index obtained with the multiple-response model (MRM) applied. The overall profile of the set of beliefs related to a subject, represented by the standardized attitudinal index, would be the

* Translator's note: Before the feminist movement arose, in situations including both genders it was customary to use the masculine pronoun. Today, however, pronouns of both genders are used to avoid what is now seen as sexist language. To avert the awkwardness of continually using "s/he", "his/her", we shall, in this paper, sometimes use the feminine pronoun, and sometimes the masculine.

result of the individual evaluation of each of the sentences for each item, i.e., the specific beliefs on the subject.

STS issues are complex, dialectical, and have no absolute references, so that they conform more to the learning of attitudes and values than to the learning of science skills or procedures—which is why we use the concept of attitude as the best. A methodological consequence of this decision is the emphasis that must be put on the correct definition of an particular attitude, which requires pinpointing. The specific object of that attitude. The general structure of the cocts and the multiple-option format of the questions used contributes to this end, and also clearly explains the composition of the more complex themes. The object of the attitude evaluated in every item is the topic, and the phrases express a group of singular beliefs regarding it.

The application of the COCTS and the new MRM technology used, permit a detailed qualitative and qualitative analysis of the students' beliefs regarding STS issues, as well as a diagnosis of the strongest and weakest aspects, such as those summarized in this study.

As a general consideration, it is worthy of note that the differences between the scores get lower as one moves from more concrete attitude indices (e.g., the index of a sentence) to increasingly global indices, such as the index of a category (set of sentences), the index of an item (set of three categories), or the index of a group of items (a dimension or a subdimension). Perhaps the reason for this lies in the well-known statistical effect of the *law of large numbers* applied to the centralizing parameters, so that the mean always tends to smooth out the more extreme differences as the generality of the mean and the number of cases included increase. As is typical of the centralizing measures, the more individuals and items are included, the greater the ability to approach the mean of the set, and the smaller the specific potential for a concrete description.

The methodology used in this study to investigate STS attitudes allows us to show that the thinking of students demonstrates some of the myths about the nature of science identified by McComas (1996, 1998). However, it should be noted that the items used in this study were selected to cover a wide range of STS topics, not to identify these myths in particular. In spite of that, one can observe the way many of them appear in students' *naïve* attitudes.

In the results obtained, the myth of science as individual effort is related to the rejection of the belief that the motivation of scientists is "to gain recognition, because otherwise their work will not be accepted" (6011A).

The fable that sees law as mature hypothesis (hypothesis become theories, which in turn become laws) is shown when one believes that:

A hypothesis is proven by experiments; if it proves successful it becomes a theory and, after a theory has been proven true many times by different people and is managed for a long time, it becomes a law (90511A).

The belief that there is a general and universal scientific method is expressed in the lack of recognition that "there is really no such thing as a scientific method."

The justification of scientific knowledge by the careful accumulation of evidence is identified in the adherence to the statement, "Social demand for understanding nature stimulates the accumulation of scientific knowledge" (20821A).

The idea that science is more procedural than creative is seen in the belief that "any good scientist will make the same discovery as any other good scientist"(60511A).

The myth of empiricism as the main road to scientific knowledge is evident in the *naïve* belief which maintains that "...scientific opinion is based entirely on observable facts and scientific understanding" (70211A).

Thus, some weak aspects of students' beliefs significantly coincide with the myths suggested by McComas (1996, 1998), a similarity which might be even greater if one took into account that these myths are centered in the epistemology of science, while the sociological aspects of science and technology are not represented. Neither are there reflected other inappropriate STS attitudes, such as those related to the social dimension of science and technology; some of these inappropriate attitudes have been identified in this study (Table VI); for example:

1) Research continues in spite of religious and cultural groups, and regardless of cultural or ethical views.
2) Scientists are concerned about the possible adverse effects of their discoveries, and verify them.
3) Scientists make better techno-scientific decisions because they have training, data and knowledge.
4) The decision to use a new technology depends mainly on its benefits to society.

The results obtained prove that students' thinking can be contradictory and inconsistent, a situation nothing strange in attitude-evaluation studies. Indeed, an analysis of the different dimensions shows that various items of the same dimension can lead to very different values, and that even within the same item, the different phrases also present very different indices. One might think that a person's having either an appropriate attitude or a naïve one concerning an item would mean that this attitude would remain more or less homogeneous in all the sentences that comprise it. On the contrary, the results show a wide dispersion, revealing inconsistency in the students' attitudes, without there seeming to have arisen any sort of personal conflict. Consequently, it is necessary to educate STS attitudes, addressing them in an explicit, reflective manner in the science curriculum.

This study shows the complexity of attitude formation, and provides additional evidence on the methodological precautions that must be taken in order to obtain a more valid and reliable attitudinal assessment (Munby, 1997, Gardner, 1996;

Ramsden, 1998). The risk of invalidity inherently associated with means of evaluating attitudes is great when one attempts from a few sentences (sometimes with one sentence only), to infer an attitude toward a more general or broad subject. Indeed, if the contribution to the definition of the participants' attitudes may be skewed, depending on the content of the sentence, it is obvious that the validity of attitudinal means based on responses to a series of sentences depends on the representativity of the statements applied, either in a traditional Likert questionnaire or in an interview. Consequently, a single sentence can skew the measurement obtained, so that the use of a single item to assess an attitude must be avoided.

The discrepancy observed between the opinions of the sentences of the same item (or the various specific issues of the same dimension) clearly demonstrates the limited validity of assessment methods based on using isolated sentences to assess attitudes, and the need for valid, but necessarily complex methods, to obtain a more reliable assessment and stronger results.

The method proposed in this study, which evaluates STS attitudes appropriate to specific topics based on the indicators of a diverse set of sentences related to a topic, fulfills the same functions as do the similar ones used in an interview to clear progressively the participant's thinking, but it does so in a more structured and premeditated manner.

5.1. Educational Implications

The individual diagnosis of STS attitudes has important implications for science teaching. A diagnosis of this type facilitates the planning of didactic training activities aimed toward improving or changing STS attitudes, and toward adaptation. This possibility is especially valuable when combined with the plurality and diversity of beliefs observed in the students.

The major differences between the STS attitudes of a relatively small set of participating students suggest that the most appropriate training action would be more effective if it were more personalized; that is, adapted to the diverse needs of each person. In this sense, the detection of strengths and weaknesses is key, since educational intervention should be supported by the strongest, and aimed at improving the weakest.

Individual diagnostic accuracy combined with the plurality of attitudes obtained, provides a valuable resource for educational intervention aimed at changing attitudes. Research on attitudinal change has shown that one of the most powerful factors in achieving this is peer influence. One possibility would be to organize work and discussion groups among students, i.e. learning communities led by those who both have the right attitudes, and are the learners' equals. Individual diagnostic assessment allows the identification of students having the most appropriate attitudes in every sentence, item or dimension. Furthermore, these students could lead others in learning, in those aspects they master more completely.

Finally, to complement the didactic activity and to achieve the desired attitudinal change, these might also help: appropriate and suitably selected readings for raising the awareness of logical inconsistencies between more appropriate ideas and less appropriate ones; dealing with the conflict between opposing ideas in group discussion; and explanations designed to address each of the weaker aspects.

Educational intervention could be performed using various methods and instruments belonging to the field of general didactics itself. Explicit personal reflection should be, in any case, a basic tool for achieving attitudinal change, regardless of the teaching method used.

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