Chapter 8
Teachers' Beliefs on Science-Technology-Society (STS) and Nature of Science (NOS): Strengths, Weaknesses, and Teaching Practice

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1 Introduction

The nature of science (NOS) represents an evolving field of meta-knowledge about science as a way of knowing, which has been constructed over many years from the interdisciplinary reflections of philosophers, sociologists, technologists, historians of science, scientists, and science educators. The NOS literature still maintains a kind of uneasy mixture of philosophical (epistemology), historical, social, and technological issues, which essentially involve the relationships of science, technology, and society (STS), the influence of society on science and technology (ST), the influence of ST on society, the relationships between science and technology, and the internal sociology of ST communities (values, principles, methods, commitments, etc.). These interdisciplinary roots and the usually evolving character of science have led to different visions, so that scholars do not agree on any shared specific definition of this complex field (Deng et al. 2011; Lederman 2007).

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However, the need in science education to construct a NOS curriculum that is at once authentic, practical, interesting, and viable for students has been driving a trend towards consensus about NOS, as is manifest in both the scholarly literature and many school science curricula. Indeed, the literature exhibits a consensual reductionist tendency to consider that the philosophical issues (epistemology of science) form the real core of NOS as against the remaining social, technological, and historical issues (Bartholomew et al. 2004; Millar 2005; Tsai and Liu 2005).

Other authors claim that NOS could be viewed from a broader perspective, not just reduced to the epistemology of science as the former studies suggest. Rather, a constellation of social, technological, and historical issues that are collectively labelled relationships of science with technology and society (STS). For instance, research on socio-scientific issues stresses the importance of social and ethical issues for science education (Sadler 2011; Zeidler et al. 2005). Aikenhead and Ryan (1992) suggest a complete and integrated framework of STS issues in nine dimensions, in which epistemology appears as one of these dimensions, although the whole framework is needed to account for the complexity of the STS orientation which involves the concepts, impacts, and solutions of science and technology in society (social, environmental, economic, cultural, ethical, etc.). Recently, Matthews (2012) has also argued for a broader set of consensual NOS features than the seven tenets of Lederman, so as to more faithfully reflect the multifaceted and contentious character of the NOS area. A recent inventory of specific consensual STS-NOS issues, drawn from different empirical studies, sets up today sound evidences in support of a broader STS orientation for the traditional NOS area (Vázquez and Manassero 2012).

Whether the approach will be to broaden STS or to reduce the epistemological orientation in NOS research is likely to depend on the relative importance assigned to STS relationships as against epistemological issues, since both of them could be deemed knowledge about science. Indeed, even the main advocates of the epistemological orientation for NOS acknowledge the STS orientation as a component of NOS under a diversity of generic formulations (e.g., scientific knowledge is "… socially and culturally embedded" – Lederman 2007, p. 833). Since much of current research on students' and teachers' beliefs has been performed under the umbrella of NOS, the present study will also come under this label, even though it assumes the broader STS orientation. Indeed, the instrument implemented here involves a broad mix of issues concerning epistemological tenets, the scientific community, and the interactions of science with society and technology (Vázquez et al. 2012).

The main relation connecting science teachers and STS-NOS issues is that the latter are today widely accepted as an indisputable target of science education for the attainment of authentic scientific and technological literacy for all (Rudolph 2000; DeBoer 2000; Millar 2006). Thus, NOS needs to be incorporated into the school science curriculum (e.g., Abd-El-Khalick and Lederman 2000; Lederman 1992), and indeed many current school science curricula already include the development of issues of NOS (AAAS 1993; Millar and Osborne 1998).

Consequently, research on teacher thinking on NOS is of interest for science education, although reviews of the last decade's literature (García-Carmona et al. 2011;

Lederman 2007; Liang et al. 2009; Tsai 2007) unfortunately reflect the inadequate comprehension of NOS and the naivety of the visions teachers hold on the topic. Teachers' understanding of NOS deviates from the modern views of science that the history, philosophy, and sociology (HPS) of science and technology studies have established, without forgetting their contentious and debatable status. Further, teachers' understanding shows scarce progress, as it is quite similar to that observed in previous years (e.g., Abd-El-Khalick and Lederman 2000; Lederman 1992; Nott and Wellington 1993). Teachers' beliefs lie close to traditional, positivist (logical empiricist), and idealistic views of S&T. They are similar to the McComas' list of myths (1996) and overly contrary to the list of consensual ideas on science drawn from the HPS modern views (Bartholomew et al. 2004; Lederman 2007; Vázquez and Manassero 2012). Teachers usually understand science as being either a static body of knowledge (thus, true and unchangeable) or a process of discovering what is out there, not as a human process of inventing explanations and theories (e.g., see a recent review in Lederman 2007).

Teachers' NOS beliefs are central for science education, because they decisively influence their classroom teaching practices. For instance, teachers who believe that science is an accumulation of knowledge tend to do experiments by following the textbook instructions and getting the right answers. In contrast, teachers who believe that science indeed changes are more likely to encourage students' discussions (Smith and Scharmann 1999). Furthermore, some studies have found that teachers with adequate NOS understanding do not necessarily automatically teach NOS issues in their classrooms (Lederman 2007). Although there are many factors involved in the decisions to teach NOS, in general, teachers lack the relevant pedagogical skills to do so effectively. Research has shown that some teaching practices are keys for curriculum NOS issues to be suitably addressed: planning, designing, and evaluating the NOS content; giving learners explicit access to appropriate NOS concepts; and providing general reflection and coherence between NOS tenets and the representations of science and technology in the classroom (Lederman 2007).

Until recently, scarce research on teachers' beliefs about NOS has focused on non-Anglo-Saxon, in-service teachers, and far less on Iberian teachers. Obviously, it is quite difficult generalizing about the complex reasons of this difference, though it can be ascertained that Iberian countries introduced STS-NOS contents, both in curricula and in science teacher training, much delayed in relation to Anglo countries. For instance, Spanish school science curricula explicitly presented STS-NOS contents from secondary to high school under the Education Act of 2006, though isolated proposals can also be documented earlier; the situation of science teacher training is even worse, as STS-NOS contents are not explicitly enacted, thus depending on the planning of teacher training implemented by each university. The present communication draws on data from an international cooperative investigation (Iberian-American Project of Evaluation of Attitudes Related to Science, Technology and Society – Spanish acronym PIEARCTS) that diagnoses STS-NOS beliefs across seven Iberian-American Spanish and Portuguese-speaking countries.

In particular, it presents the results of the application of a new methodological approach to assessing the STS-NOS beliefs of a large teacher sample consisting of preservice and in-service high-school science teachers. The STS-NOS beliefs are examined from a broad perspective that includes both external (relationships of science with technology and society) and internal aspects of science (its philosophy and sociology). The study is a search for empirical answers to the following questions: What are the strengths and weaknesses of secondary science teachers' beliefs on themes of STS-NOS? Do in-service science teachers understand STS-NOS issues better than their preservice counterparts?

2 Method

2.1 Sample

A master's degree is the official initial training for secondary science teachers in Spain. Their enrolment requires in turn the previous completion of a degree in science (e.g., life science, chemistry, physics, earth science, and engineering). The master's program involves both general pedagogy and specific didactics adapted to the specialization of the entrance degree.

The participants in the present study were 613 high-school science teachers – about one-third (32 %) in-service teachers, and the other two-thirds (68 %) preservice teachers. Their ages ranged from 23 to 63 years, and the sample split approximately into equal halves by gender (52 % men).

The preservice teachers were university graduates in physics, chemistry, biology, etc., who were following a master's program in science education to be accredited as prospective teachers (without educational experience). The in-service teachers were practicing teachers with variable practical experience in teaching science in the classroom. Since both the pre- and the in-service science teachers had received similar initial training in a pre-Bologna higher education system, overall they differed only in teaching experience.

2.2 Instrument

The Questionnaire of Opinions on Science, Technology and Society (Spanish acronym, COCTS) is an adaptation to the Spanish language and culture of the Views on Science-Technology-Society (VOSTS) pool (Aikenhead and Ryan 1992) and Teacher's Belief about Science-Technology-Society (TBA-STS) items (Rubba et al. 1996). In particular, COCTS is a pool of 100 multiple-choice items, which inherits the credit of the empirically developed VOSTS and TBA-STS items as one of the best pencil-and-paper instruments to evaluate STS-NOS beliefs, as the empirical development of the items guarantees the item validity (see the argumentation on this point in Aikenhead and Ryan 1992) and Lederman et al. (1998, p. 610) consider the VOSTS a valid and reliable instrument for investigating conceptions on the nature

Table 8.1 Labels of the items included in the two questionnaire forms (Form 1 and Form 2) across the structural dimensions of STS-NOS issues. A short description of the item's issue follows each key number

Item groups/dimensions (key)	Form 1 items (key/issue)	Form 2 items (key/issue)
(a) Definition of S&T (1)	F1_10111 science	F2_10211 technology
	F1_10411 interdependence	F2_10421 interdependence quality of life
(b) STS interactions (3)	F1_30111 STS interaction	
Influence of society in S&T (2)	F1_20141 country's government policies	F2_20211 industry
	F1_20411 ethics	F2_20511 educational institutions
Influence of S&T in society (4, 5)	F1_40161 social responsibility contamination	F2_40131 social responsibility information
	F1_40221 moral decisions	F2_40211 social decisions
	F1_40531 life welfare	F2_40421 application to daily life
		F2_50111 union two cultures
Internal sociology of science (6, 7, 8)	F1_60111 motivations	F2_60521 gender equity
	F1_60611 women's under-representation	F2_70211 scientific decisions
	F1_70231 consensus decisions	F2_70711 national influences
	F1_80131 advantages for society	
(c) Epistemology (9)	F1_90211 scientific models	F2_90111 observations
	F1_90411 tentativeness	F2_90311 classification schemes
	F1_90621 scientific method	F2_90521 role of assumptions
		F2_91011 epistemological status

of science. All the items have a common multiple-choice format: the stem presents a specific STS-NOS issue, which is followed by variable number of sentences (from 4 to 12; mean around 7), each labelled with a letter A, B, C, etc. Each sentence states a different rationale position (belief) on the stem issue, using nontechnical, familiar, and simple language (Vázquez et al. 2005, 2006).

The nine-dimensional structure of the original VOSTS is used here to classify the items into three main groups (leftmost column of Table 8.1), which correspond to the two underlying component fields of STS-NOS issues, i.e., STS interactions (groups a and b) and the epistemology of scientific knowledge (group c). Each item is labelled by a five-digit number. The first digit identifies the dimension, 1–8 for the different aspects of STS (internal sociology of science, etc.) and 9 for epistemology; the second pair of digits corresponds to themes; and the third pair of digits 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 (see detailed examples in Tables 8.2, 8.3, and 8.4). The main innovation of COCTS is the categorization of each sentence into a scheme of three categories (Adequate, Plausible, Naïve) by a panel of 16 experts on STS issues through a complex process of discovering the majority consensus (further details have been presented elsewhere: Vázquez and Manassero 1999; Vázquez et al. 2005, 2006). Moreover, some statements include the coding _C_ inserted before the tag number, which means the statement represents an idea that achieved the experts' consensus (over two-third of experts agreed on the category they assigned to the statement). The research team consensually selected 30 items that were distributed into two 15-item research booklets (F1 and F2; see Table 8.1) to provide a balanced coverage of the different dimension issues and for practicality of application (answering time under the person's fatigue threshold, average 50 min; easy self-administration; etc.). Each participant anonymously answered one randomly assigned form (F1 or F2), either on a pencil-and-paper brochure or on a web page; roughly half of the participants answered Form 1 (309), and the other half Form 2 (304).

2.3 Procedures

The respondents are not compelled to select any sentence. Rather, they are asked to rate their agreement (1, total disagreement; 9, total agreement) on each sentence of the items and are provided with alternative ways to not rate a sentence (not know, not understand, or leave it blank). These sentence scores are transformed into a homogeneous invariant normalized statement index in the interval [−1, +1] through a scaling procedure that takes into account the category of each statement (Adequate, Plausible, Naïve) assigned by the experts (further details in Vázquez et al. 2005, 2006).

For instance, an appropriate statement (_A_) expresses an adequate view on the issue, so that 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 (_N_) 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 (_P_) 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. Thus, the index meaning is invariant across all sentences: the higher (lower) the index score, the higher (lower) the belief's correctness according to current knowledge according to the history, philosophy, and sociology of S&T (Vázquez and Manassero 1999; Vázquez et al. 2006).

Thus, the closer to the maximum positive value (+1) an index is, the more informed (close to experts' conceptions on NOS) the respondent's view is; while the closer to the negative value (−1) the index is, the more misinformed (detached from current NOS conceptions) the respondent's view is. As misinformed conceptions are associated to the lowest negative values of the index, and the informed ones are

Table 8.2 Text of item 90621 (scientific method), displaying the text of sentences (center), 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)

			Mean indices		
Variable	Category	Item	Sentence	Category	Item
		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	–0.2422 (.5574)	–0.2142 (.4886)	
F1__90621B_N_	Naïve	B. The scientific method should work well for most scientists; based on what we learned in school	–0.1869 (.4936)		
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	0.4854 (.4671)	0.4854 (.4671)	0.0400 (.2820)
F1__90621D_P_	Plausible	D. The best scientists are those who use any method that might get favorable results (including the method of imagination and creativity)	–0.0862 (.6506)	–0.1416 (.5034)	
F1__90621E_P_	Plausible	E. Many scientific discoveries were made by accident, and not by sticking to the scientific method	–0.1935 (.6470)		

Note the letters (A, B, C, D, etc.) 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)

Table 8.3 Complete text of item 10421 that displays the classification of its sentences as weaknesses (italics), strengths (bold), or medium, according to their mean indices for the teachers

10421 In order to improve the quality of life in our country, it would be better to spend money on technological research RATHER THAN scientific research	Mean (SD)	Category
A. Invest in technological research because it will improve production, economic growth, and unemployment. These are far more important than anything that scientific research has to offer	*.5332 (.4741)*	*N*
Invest in both:		
B. Because there is really no difference between science and technology	−.0348 (.6441)	P
C. Because scientific knowledge is needed to make technological advances	*−.4702 (.5414)*	*P*
D. Because they interact and complement each other equally. Technology gives as much to science as science gives to technology	*.5861 (.4347)*	*A*
E. Because each in its own way brings advantages to society. For example, science brings medical and environmental advances, while technology brings improved conveniences and efficiency	−.0712 (.5912)	P
F. Invest in scientific research – that is, medical or environmental research – because these are more important than making better appliances, computers, or other products of technological research	.1752 (.5198)	N
G. Invest in scientific research because it improves the quality of life (for example, medical cures, answers to pollution, and increased knowledge). Technological research, on the other hand, has worsened the quality of life (for example, atomic bombs, pollution, automation, etc.)	*.3750 (.5534)*	*N*
H. Invest in neither. The quality of life will not improve with advances in science and technology, but will improve with investments in other sectors of society (for example, social welfare, education, job creation programs, the fine arts, foreign aid, etc.)	*.8007 (.4002)*	*N*

represented by the highest positive values of the index, for brevity, they are simply referred to as "positive" or "negative" leaving out any biased meaning of these words.

The sentence's indices are the basis for further computations and statistics. For instance, a mean category index can be computed by averaging the sentences' indices belonging to each category; in turn, the average of the three category indices produces the weighted item global index, which represents the quantitative assessment of the overall conception about the item issue. This scheme describes the teacher's NOS thinking through 115 invariant indices for each form (about 100 sentence and 15 item indices – leaving aside category indices), thus being able to produce detailed profiles for persons, groups, or the overall sample (Table 8.2).

The indices allow the use of inferential statistics for hypothesis testing, which can be applied to compare groups (preservice vs. in-service teachers), or to set up cutting points to identify the strengths (highest positive), weaknesses (lowest negative), and

Table 8.4 Descriptive statistics of the 30 items (Form 1 and Form 2) for the whole sample of teachers (n valid cases, average item index and standard deviation)

Items	n	M	SD
F1_10111 science	309	0.275[a]	0.203
F1_10411 interdependence	308	0.231	0.278
F2_10211 technology	303	−0.050	0.239
F2_10421 interdependence quality of life	302	0.288[a]	0.222
F1_20141 country's government policies	307	0.283[a]	0.214
F1_20411 ethics	306	−0.094	0.303
F2_20211 industry	300	0.209	0.270
F2_20511 educational institutions	298	0.219	0.255
F1_30111 STS interaction	302	0.484[a]	0.293
F1_40161 social responsibility contamination	306	0.469[a]	0.207
F1_40221 moral decisions	304	0.232[a]	0.219
F1_40531 life welfare	306	0.010	0.372
F2_40131 social responsibility information	297	0.229	0.244
F2_40211 social decisions	295	0.046	0.293
F2_40421 application to daily life	293	−0.115	0.259
F2_50111 union two cultures	293	0.287	0.297
F1_60111 motivations	303	0.026	0.240
F1_60611 women's under-representation	304	0.218	0.289
F2_60521 gender equity	292	0.271[a]	0.214
F1_70231 consensus decisions	297	0.031	0.313
F2_70211 scientific decisions	286	0.042	0.284
F2_70711 national influences	288	0.073	0.298
F1_80131 advantages for society	304	0.095	0.242
F1_90211 scientific models	291	0.081	0.311
F1_90411 tentativeness	299	0.143	0.308
F1_90621 scientific method	295	0.040	0.282
F2_90111 observations	288	−0.174	0.402
F2_90311 classification schemes	292	0.139	0.255
F2_90521 role of assumptions	290	0.187	0.321
F2_91011 epistemological status	291	0.092	0.295

[a]Items whose mean indices are larger than one standard deviation

neutral or medium beliefs (Vázquez et al. 2006). The criteria for relevance were the statistical significance ($p < 0.01$) and the effect size of the differences (differences measured in standard deviation units; $d > 0.30$).

3 Results

The diagnostic method evaluates each item through a set of variables that includes the sentence indices, the three category average indices, and the overall item index (average of the three categories). The grand means of the sentence indices for the whole teacher sample were slightly different for Form 1 (m = 0.1862; SD = 0.5456) and Form 2 (m = 0.0809; SD = 0.5531); both are positive, but quite close to the null value. This result can be interpreted as an indicator of neutral, although somewhat positive, beliefs towards STS-NOS issues; some positive indices compensate the negative ones to produce this approximately neutral value for the overall mean of the entire sample, which suggests that informed beliefs coexist with other poorly informed beliefs.

The following example presents the classification of the sentences of item 10421 as weakness, strength, or medium, according to their mean index scores.

The Table 8.3 illustrates some common qualitative features detected through the new method in the results for all items: on each issue (item), the teachers hold at the same time strengths and weaknesses. In the example of Table 8.3, several sentences represent positive beliefs (A, D, G, H), while the remaining sentences represent uninformed beliefs, either clear weakness (C) or beliefs that do not attain a sufficiently high level to meet what the teachers need for quality teaching of NOS (B, E, F). Overall, this incomplete understanding of STS-NOS issues means that teachers do not master enough the issues to cope with their teaching in the classroom.

3.1 Teachers' Strengths and Weaknesses

The distribution of the average item indices is displayed in Table 8.4 for the items of both forms (F1 and F2). The two forms show asymmetrical distributions among positive and negative for item indices, where most of the items (26) are located in the positive area (F1 has only one item with negative mean index scores).

The items with the highest/lowest indices (more than one standard deviation above/under zero) identify the teachers' strengths and weaknesses. The list of F1 and F2 items which represent teachers' strengths is the following: F1_30111 STS interaction, F1_40221 moral decisions, F1_40161 social responsibility contamination, F1_20141 country's government policies, F1_10111 science, F2_10421 interdependence quality of life, and F2_60521 gender equity.

A few items (4) had negative scores on both forms (F1 and F2), though their mean indices did not attain low enough scores to be considered symmetric to the positive items (lower than one standard deviation under zero). Nonetheless, the items with negative indices, which represent a teacher's weaknesses, are the following: F1_20411 ethics, F2_40421 application to daily life, and F2_90111 observations.

From the perspective of teaching science, a good science teacher should have sufficient understanding of STS-NOS issues. Applying the criterion of relevant positive indices ($d > 0.30$ over zero) to the average item indices, one can conclude that approximately half of the items reflect the teachers having sufficient understanding of STS-NOS. Complementarily they need significant training on approximately another half of STS-NOS issues.

Similarly, the same overall analysis could be applied to the sentence variables with the highest positive and lowest negative indices to identify specific strengths and weaknesses. Each of the hundred sentences represents a specific belief on NOS, and the whole set conforms the spectrum of science teacher's thinking on STS-NOS. Due to space constraints, it is not possible to reproduce this extensive data here; instead, some main features of the index distributions are described.

The index distribution spectrum is slightly skewed towards positive scores since the number of sentences attaining positive indices is twice the sentences attaining negative indices. However, about a quarter of the sentences (28 %) surpass the relevance threshold ($d > 0.30$) of high positive mean indices over zero, so that these can be considered the teachers' relevant adequate conceptions on STS-NOS. The remaining sentences (72 %), whether positive or negative, represent sentences with insufficient scores to allow considering teachers to be sufficiently prepared, as these beliefs reflect. Overall, teachers did not attain a satisfactory level of understanding for over two-thirds of the sentences.

Again, the sentence mean indices allow identifying the positions with the highest positive indices (the best informed beliefs, or strengths) and the lowest negative indices (the worst informed beliefs, or weaknesses) to be identified.

Most sentences with the highest positive indices belong to the Appropriate (_A_) or Naïve (_N_) category sentences, while also noteworthy is the absence of Plausible (_P_) sentences. On the contrary, most sentences displaying to the lowest indices correspond to the Plausible or Naïve categories. Next paragraph shows comments on specific sentences for some selected items.

3.2 Qualitative Analysis of Teacher Thinking

The qualitative analysis of the sentence content allows one to examine the teachers' thinking in greater depth. For instance, the sentence F2_C_40211D_A_social decisions gets the highest item index and poses the issue of whether scientists and engineers should be the only ones to make decisions on the scientific affairs of our country. The teachers attained a high index in agreeing with the Appropriate sentence which states that the decision should be taken on a shared basis (the opinions of scientists and engineers, other specialists, and informed citizens should be taken into account in decisions that affect our society). Among the set of lowest index sentences, one can find the Naïve sentence F1_C_90621A_N_scientific method (Table 8.2), which states that the scientific method ensures valid, clear, logical, and accurate results (thus, most scientists will follow the steps of the scientific method). Teachers did not recognize the naïvety of this sentence as they attained a very low index on it. The two previous mentioned sentences are both examples of appropriate and naïve ideas often held by teachers and reported in the literature as myths of science (i.e., McComas 1996).

Qualitative analysis can be extended to each item to better understand teacher thinking on each topic, which is exemplified below through two items to meet the space constraints (Table 8.5).

Table 8.5 Mean indices, valid cases, standard deviation, and texts of items 40211 and 90311 for qualitative analysis

Items and sentences			Valid n	M	SD
40211 Scientists and engineers should be the ones to decide what types of energy our country will use in the future (for example, nuclear, hydro, solar, or coal burning) because scientists and engineers are the people who know the facts best					
Scientists and engineers should decide:					
F2_C_40211A_N_social decisions	A.	Because they have the training and facts which give them a better understanding of the issue	293	–0.064	0.574
F2_C_40211B_N_social decisions	B.	Because they have the knowledge and can make better decisions than government bureaucrats or private companies, both of whom have vested interests	292	–0.150	0.573
F2__40211C_P_social decisions	C.	Because they have the training and facts which give them a better understanding; BUT the public should be involved – either informed or consulted	294	–0.122	0.592
F2_C_40211D_A_social decisions	D.	The decision should be *made equally*; viewpoints of scientists and engineers, other specialists, and the informed public should all be considered in decisions which affect our society	295	0.638	0.406
F2__40211E_P_social decisions	E.	The *government* should decide because the issue is basically a political one; BUT scientists and engineers should give advice	295	0.034	0.607
F2__40211F_A_social decisions	F.	The *public* should decide because the decision affects everyone; BUT scientists and engineers should give advice	293	–0.035	0.581
F2__40211G_P_social decisions	G.	The *public* should decide because the public serves as a check on the scientists and engineers. Scientists and engineers have idealistic and narrow views on the issue and thus pay little attention to consequences	293	–0.077	0.641
F2__40211H_P_social decisions	H.	It depends of the type of decision; it is not the same thing to decide on the nuclear disarmament or on a baby. In some cases the scientists could make the decision, but in other, the citizens or the stakeholders should make it	292	–0.050	0.676

90311 When scientists classify something (for example, a plant according to its species, an element according to the periodic table, energy according to its source, or a star according to its size), scientists are classifying nature according to the way nature really is; any other way would simply be wrong					
F2_C_90311A_I_ classification schemes	A.	Classifications match the way nature really is, since scientists have proven them over many years of work	287	0.084	0.498
F2_C_90311B_I_ classification schemes	B.	Classifications match the way nature really is, since scientists use observable characteristics when they classify	287	–0.046	0.517
F2__90311C_P_ classification schemes	C.	Scientists classify nature in the most simple and logical way, but their way is not necessarily the only way	290	–0.190	0.585
F2__90311D_A_ classification schemes	D.	There are many ways to classify nature, but agreeing on one universal system allows scientists to avoid confusion in their work	290	0.653	0.411
F2_C_90311E_A_ classification schemes	E.	There could be other correct ways to classify nature, because science is liable to change and new discoveries may lead to different classifications	292	0.642	0.388
F2_C_90311F_A_ classification schemes	F.	Nobody knows the way nature really is. Scientists classify nature according to their perceptions or theories. Science is never exact, and nature is so diverse. Thus, scientists could correctly use more than one classification scheme	289	0.420	0.552

The item (40211, scientists and engineers should be the ones to decide…) raises the issue on the most appropriate way to make social decisions about issues related to science and technology (in this case, regarding energy decisions). Again the profile of teachers is low (around zero) along almost all statements, although teachers broadly guess right the most appropriate sentence (D, …all (must) be considered in decisions which affect our society). Responses to this item exemplify very well the inconsistent and weak understanding of STS-NOS subjects by teachers: when teachers mostly recognize the equal participation of different stakeholders in decisions, just by applying simple logic, teachers should be able to reject statements that recognize either the participation of only one part or unequal participation in decisions.

The item (90311) on the epistemological status of scientific classifications shows a clear positive profile of teachers' understanding, as the three appropriate sentences (D, E, F) exhibit very high average indices. Unexpectedly, the other three sentences do not reach high indices, as it would be enough for teachers implementing elementary logical deduction from their major adherence to the appropriate sentences. For example, adherence to the possibility of different ways of classifying (D) and its change over time (E) must lead logically to major rejection of the sentences A and B (the only way is presumed nature really is) or C (classifications are simple and logical), but this is not the case (low mean indices). This feature suggests that the high commitment of teachers to the adequate complex, instrumental, and evolutionary nature of classifications (sentences D, E, F) is not the consequence of teachers' sound epistemological thought, but likely the simple reminder of textbooks, which usually display different classification schemes on the same issue (animals and plants, the soil's geological ages, chemicals, heavenly bodies, etc.), which also show change over time (E).

3.3 Differences Between Preservice and In-Service Teachers

The present methodological approach allows the application of inferential statistics in hypothesis testing. In particular, the simplest form of testing is group comparison, which is applied here to compare the STS-NOS beliefs of pre- and in-service teachers. To determine which variables might display significant differences between groups, a two-way between-groups analysis of variance was conducted to explore the impact of teaching practice on teachers' STS-NOS understanding, as measured by the 300 variables of items, categories, and sentences (dependent variables) (Figs. 8.1 and 8.2).

Overall, few variables (19 for the Form 1, and 24 for the Form 2 of the total variables involved in the two forms) displayed a statistically significant major effect ($p<0.01$; $d>0.30$) between in-service and preservice teachers. However, the differences did not have the same sign – some were positive (in-service teachers scoring higher than preservice teachers), and others were negative (in-service teachers scoring lower than preservice teachers) (Fig. 8.2). Thus, relevant differences not only were relatively scarce, but also they did not display the same trend (favoring one group over the other) across all the significant variables.

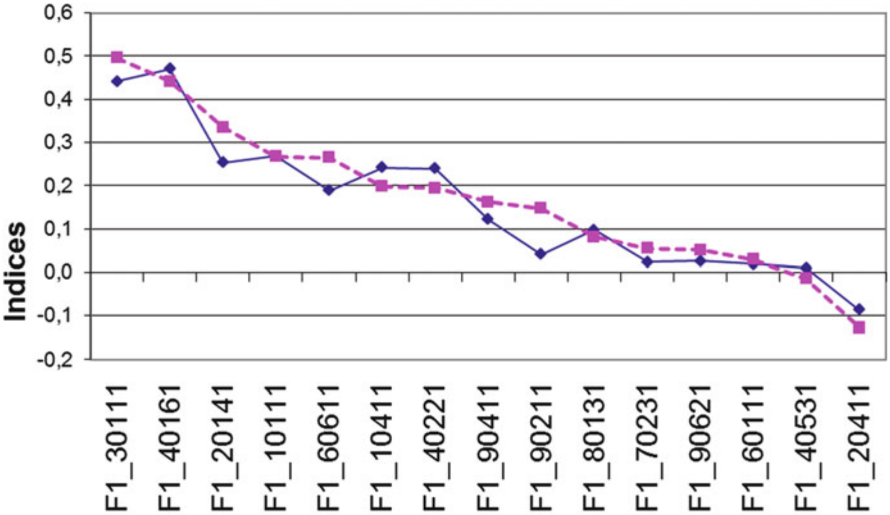

Fig. 8.1 Average item indices for in-service (*dotted line*) and preservice (*continuous line*) teachers (Form 1)

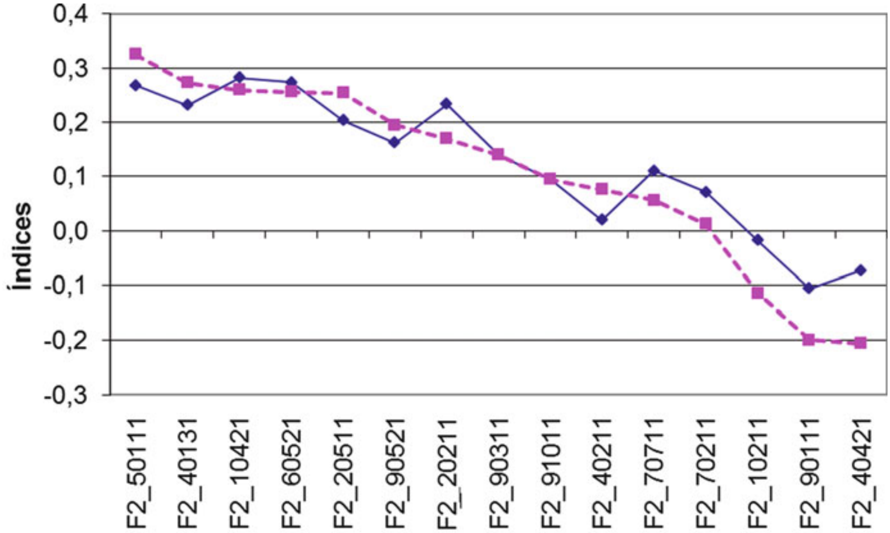

Fig. 8.2 Average item indices for in-service (*dotted line*) and preservice (*continuous line*) teachers (Form 2)

In sum, the results do not support the hypothesis that the practice of science teaching improves teachers STS-NOS beliefs. This means that improving STS-NOS understanding cannot rely on implicit practices, but instead might require explicit teaching of STS-NOS contents.

4 Conclusions and Implications

The new instrument (each sentence was categorized by a panel of experts) and methodological approach (new answering model and invariant standardized indices) described above improves the quality, validity, and reliability of the original instruments and avoids the usual objections against written questionnaires, such as participants' forced answers (choosing just one sentence) and the like. Moreover, the new approach helps to identify such qualitative features as profiles, strengths, and weaknesses in teachers' understanding of STS-NOS issues; further, the normalization of the scores and the standardization of the analyses allow standardized application and hypothesis testing statistics, such as between-group comparisons or comparisons among researchers. The method is also applicable to rapid and straightforward assessments of large representative samples, overcoming the limitations of case studies or open questionnaires to small samples, to really identify teachers' beliefs that are representative of teachers, either the strongest ones (those that closely match the experts' current understanding) or the weakest ones (those that are contrary to the experts' understanding).

The assessment instrument and method fit the requirements suggested by Allchin (2011) for appropriately assessing functional STS-NOS understanding: authentic context; well-informed analysis; adaptability to diagnostic, formative, or summative evaluation; adaptability to single, mass, local, or large-scale comparative use; and respect for relevant stakeholders. For instance, the research project PIEARCTS is an example of large-scale applications across seven countries and involving over 16,000 valid responses (Bennássar et al. 2010; Manassero et al. 2010).

The results provide a global and detailed picture of teachers' STS-NOS beliefs that is more complex than usually described (Lederman 2007): the teachers have inappropriate beliefs coexisting with appropriate ones across the entire range of STS-NOS topics. Many teachers' STS-NOS beliefs (about two-thirds of the beliefs examined) do not attain the high level required for quality teaching of STS-NOS. As the Spanish teachers involved in this study have not received specific STS-NOS training, their profiles of beliefs could be explained through a mixture of factors from informal education, such as personal reflection along years of experience on science teaching, shared exchanges with colleagues, and the reinforcement of distorted images of science conveyed by the media, the textbooks, etc. (Hodson 2009).

It is usually agreed that years of teaching improve a teacher's pedagogical content knowledge, so that the in-service teachers should have attained higher scores than the preservice teachers (Abd-El-Khalick and Lederman 2000; Lederman 2007). This would now seem to be a rather optimistic view since the comparisons between the pre- and the in-service teachers revealed scarce relevant differences. Indeed, the differences in favor of preservice teachers balance out those in favor of the in-service teachers, and the two groups seemed more similar than different. Spanish science teachers, whether in-service or preservice, have not been trained institutionally in STS-NOS issues (control variable), so that the present results provide evidence that science teaching practice by itself does not contribute to refining teachers' beliefs.

Accordingly, it should not be expected that teaching experience may (implicitly) contribute to training science teachers in STS-NOS. Complementarily the results are coherent with current compelling evidence in favor of explicitly teaching STS-NOS in order to attain effectiveness (Lederman 2007).

Nevertheless, the teachers' appropriate beliefs could be educationally invaluable because they could serve as pedagogical hooks in teacher training and in the planning of a teaching STS-NOS curriculum. Overall, the qualitative analysis, exemplified here through the mean indices for the overall teacher sample, would also be valuable for the diagnosis of individual teachers: superficial traits, weakness, and lack of logical consistency would also be identified with greater strength. At the time, teacher's awareness of the weakness of thought and subsequent cognitive conflict between adequate and naive ideas can be a basic hint for achieving conceptual change in the understanding of STS-NOS through teacher training.

All in all, the numerous inappropriate, or simply insufficiently appropriate, beliefs found in the science teachers' thinking, together with the lack of effectiveness of teaching experience to improve this situation, point to the necessity of designing and implementing both pre- and in-service teacher education programs that involve the participants in an explicit and reflexive analysis of STS-NOS topics (Hanuscin et al. 2006). The aim ought not to be for teachers to become philosophers of science, or to be more knowledgeable about STS-NOS, but for them to gain in competence teachers to teach STS-NOS issues effectively in the science classroom.

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