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Attitudes in didactic change: design and validation of a questionnaire of Primary Education teachers' attitudes toward the teaching of the Nature of Science and Technology

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Introduction: Neglecting the role of attitudes in didactic change is a serious obstacle to progressing toward the inclusion of the Nature of Science and Technology (NoST) in the classroom and achieving a scientific culture that enables the development of a critical and socially engaged citizenship capable of addressing contemporary societal challenges.

Method: For this reason, this study presents the design and validation of an assessment tool that allows attitudes to be collected in a holistic way, taking into account the cognitive, affective and conative components of trainee and practicing Primary School (PS) teachers toward the teaching of NoST. For this purpose, an instrumental-psychometric study was carried out. A sample of 210 subjects participated in the validation of the questionnaire.

Results: The statistical analyses of the scale show that it has an adequate content validity, an appropriate construct validity with a good fit to the theoretical model, and a high level of reliability. Furthermore, a first approximation to the description of the attitudinal profile indicates that thereis, in general, a positive attitude toward NoST teaching.

Discussion: It is concluded, on the one hand, that the instrument is optimal and adequate for assessing attitudes and, on the other hand, that teacher training should consider both the cognitive and affective factors that hinder the transformation of educational practices in the field of science teaching.

KEYWORDS

attitude, in-service teachers, Nature of Science and Technology, Primary Education, trainee teachers, validation of scales

1 Introduction

In today's society, citizens needs to be prepared to make informed decisions about their environment (Wagner, 2014). This is because both public and private spheres need to act on socio-scientific issues (Vázquez Alonso and Manassero Mas, 2018; García-Marigómez et al., 2023).

For this reason, scientific and technological literacy (STL) has become a fundamental pillar of Global Citizenship Education (GCE) (Fueyo et al., 2015; Thompson, 2016), as it is directly linked to the Sustainable Development Goals (ONU, 2015) and, more specifically, to Education for Sustainable Development (ESD). Through STL, it is possible to foster critical thinking, creativity, communication, and collaboration (Tenreiro-Vieira and Vieira, 2021)—competences essential for imagining and building a fairer and more sustainable world.

STL is therefore a key element in integral development. However, the propaedeutic model of science that has been and is still being transmitted from educational institutions (Vázquez Alonso and Manassero Mas, 2018) has caused multiple generations to acquire a negative (unattainable knowledge) and simplistic (little understanding) view of science, distancing and excluding them from scientific training, and from critical and active participation in socio-scientific issues and, by extension, from engagement with the challenges of global citizenship (Pérez-Foguet and Lazzarini, 2019; Yemini et al., 2019).

Given this situation, a shift in educational processes is needed one that promotes a form of scientific literacy accessible to all, understood not merely as the acquisition of content but as an interactive and participatory educational process that encourages critical awareness, civic engagement, and the construction of alternatives in favor of social justice and sustainable development.

To address the errors arising from transmissive teaching, a meta-knowledge about science based on interdisciplinary reflections emerges: the Nature of Science and Technology (NoST) (Acevedo et al., 2016). It emphasizes that science transcends content, as it is intrinsically linked to historical, philosophical and sociological circumstances.

There are currently different proposals on what to consider in the teaching and learning of the Nature of Science (NoS), such as the proposal by Lederman et al. (2002), Matthews (2012), McComas (2002), Osborne et al. (2003), the Similar Family Approach by Irzik and Nola (2014), Erduran and Dagher (2014), and the Science-Technology-Society (STS) Tradition updated by Manassero-Mas and Vázquez (2019). Although all offer important perspectives that should be taken into account, in the present research a greater affinity toward the STS Tradition can be observed, given that it incorporates aspects related to epistemology, external sociology, internal sociology and triadic influence.

The inclusion of NoS stimulates the acquisition of a more humanistic scientific-technological culture (which takes into account values and attitudes). This is crucial if we bear in mind that emotions influence and determine new learning (Mayer et al., 2000). Therefore, it is essential to consider knowing how to be (attitudes and values) so as not to fall into the error of teaching and learning exclusively cognitive content.

2 Theoretical framework

2.1 Scientific and technological literacy in primary school teacher

If we take into consideration the social and educational characteristics described above, we can argue that science education (SE) is still dominated by technical rationality. These ideas reveal the importance of approaching SE from a transformative vision.

Therefore, teacher development must be understood as a continuous process of theoretical-practical integration in which the teacher is conceived as a learner, innovator and researcher who participates in the construction of the science of teaching science (Furió and Carnicer, 2002).

In this line, the studies initiated by Shulman (1986) on the professional knowledge of teachers stand out. Specifically, from this research we focus on the ability to transform an object of knowledge into an object of teaching (Chevallard, 1985), in other words, in the pedagogical content knowledge (PCK).

The concept of PCK has been studied by various authors and teams. In the case of SE, PCK has been considered a useful theoretical framework since its origin and, therefore, we can find various proposals, such as Magnusson et al. (1999) and Gess-Newsome (2015) or the Refined Consensus (Carlson and Daehler, 2019). These models, given that they are based on advances in cognitive psychology, do not include aspects linked to affective variables, such as attitudes, in the components to be considered in teacher training and development. Other models, such as the hexagonal model (Acevedo and García-Carmona, 2016) or the ReCo model (Loughran et al., 2004), consider affective variables, but from an exclusively cognitive perspective, and the conative or emotional component of attitude is overlooked. In this sense, it is necessary to reflect on the role of these affective variables in the teaching of NoST in order to address the factors that prevent the implementation of these contents in the classroom, given their relevance in the creation of an authentic STL.

2.2 Attitudes in didactic change

Taking the previous ideas into account, it becomes clear that teacher education must be based on a process that fosters didactic change (Mellado, 2003). This change involves not only professional transformation but also personal development. Teaching is not merely a cognitive process; it requires emotional commitment, engaging both the head and the heart, as it tests personal emotional and cognitive competencies as well as professional practice (Day, 1999). Therefore, learning changes who we are and what we are capable of doing—it is an experience of identity (Wenger, 1998). Identity is particularly relevant as it highlights the need for teacher learning and development to go beyond knowledge and skills (Avraamidou, 2014).

"Emotions influence the goals that teachers set and indicate the intensity of their relationships with ideas, their beliefs about science, others, and science teaching" (Rivera Maulucci, 2013, p. 137). This idea underscores that the development of Pedagogical Content Knowledge (PCK) cannot be limited to cognitive aspects alone if it is to contribute meaningfully to the construction of professional teaching identity.

It is important to note that evidence shows changes are more likely to become embedded when they incorporate attitudes and values (Sanmartí, 2001). Therefore, the focus on attitudes must be twofold: they should be seen both as a tool to achieve positive learning outcomes, given their influence on learning and behavior, and as essential and valuable content in science education. However, at present, emotional aspects remain largely absent from teacher education programs and, consequently, from student training plans (Bisquerra and Pérez, 2007).

With regard to knowing how to be, it is important to pay attention to the concept of attitude as a construct. Attitudes can be positive and negative, i.e., they are evaluative predispositions with a motivational component that implies affectivity and a tendency to action (Sarabia, 1992). Moreover, they have a learned character (Morales, 2000) which makes them a fundamental factor to take into account in the educational field due to their influence on behavior and learning.

There are multiple models that study the structure of attitudes. Following the three-dimensional model (Martín-Baró, 1983; Hogg and Vaughan, 1995), we can identify a clear parallelism with the structure of competences and, therefore, with educational objectives. These three components are: the cognitive component, which refers to the subject's knowledge, beliefs and opinions about the object, taking a position in favor or against; the affective component, which refers to feelings, to the emotions of acceptance or rejection, liking or disliking, that are activated when faced with a stimulus; and the conative component, which refers to the declarations of intentions before the object of attitude. These components differ from one another, but converge intensely in that they share a common basis (the representation of the same attitude).

If we transfer this construct to Science Education, the literature reveals that there are problems derived from the lack of precision of the attitude, the attitude object and the absence of a single construct (Bogdan and Meneses, 2021; Manassero Mas and Vázquez, 2002; Vázquez and Manassero, 1995; Vázquez and Manassero Mas, 1997).

In this sense, the literature puts together taxonomies to organize and support the study of this construct and to define more accurately and precisely the attitudinal objects. One of the widely accepted classifications is the one proposed by Gardner (1975): attitudes toward science (a more affective and evaluative approach toward the elements involved in learning science) and scientific attitudes (with a cognitive character and linked to scientific thinking). However, the objects of attitude in science education cannot be limited to the attitude toward learning science. Hodson (1988) reveals that school is a key element in the shaping of a balanced attitude and, for this reason, he includes the attitude toward SE in his taxonomy. This category is the focus of the present study.

In summary, taking into account the ideas gathered, the manuscript is based on multiple theoretical perspectives that complement each other to support, contextualize, and operationalize the attitudinal approach (which constitutes the central construct).

3 Literature review

In recent decades, there has been an increase in interest in the study of attitudes within the theoretical framework provided by social psychology (Vázquez and Manassero, 1995). If we focus on teachers' attitudes toward SE, the systematic literature review conducted by García-Marigómez et al. (2026) reveals that, from 2015 onwards, new areas of interest have emerged, such as critical thinking, the role of ICT and media, and the influence of attitudes. Regarding the latter, the documentary analysis indicates that, within the emphasis on knowing how to be, there is a predominant focus on the cognitive component of attitudes, while the affective and conative components are largely overlooked.

The most frequently investigated attitudinal objects are beliefs or opinions about STS issues (Barnes et al., 2015; Ozturk-Akar and Dogan, 2013), self-efficacy beliefs (Clerici, 2008; Murphy and Smith, 2012), and beliefs about teaching (Aragón Núñez, et al., 2021; Mansour, 2013). Less frequently, studies on liking or interest in scientific areas (Aguirregabiria and García-Olalla, 2022; Mateos Núñez and Martínez Borreguero, 2021; Martínez-Borreguero et al., 2022) and on beliefs about pseudoscience (Cadena-Nogales et al., 2022) are encountered.

In short, although existing instruments have contributed to the assessment of teachers' views on the Nature of Science, several limitations remain, particularly when applied to Primary Education contexts. Many tools prioritize cognitive dimensions, are designed for secondary or higher education teachers, or do not explicitly integrate affective and conative components. As a result, they provide a partial view of teachers' attitudes and offer limited guidance for professional development in primary science education. The instrument developed in this study addresses these gaps through a multidimensional and context-sensitive approach.

As has been noted, numerous studies have focused on teachers' self-efficacy beliefs. However, self-efficacy represents only one dimension of the attitudinal framework of teachers, being primarily associated with the cognitive component of attitude. Therefore, this approach, limited to the cognitive dimension, fails to address the affective and conative aspects that also influence teachers' stance toward science teaching.

This issue becomes particularly relevant when considered in light of the Theory of Planned Behavior (Ajzen and Fishbein, 1980). Attitude constitutes a determining factor in the formation of intentions and behaviors. A favorable attitude may strengthen intention even when self-efficacy is low, whereas an unfavorable attitude may weaken it despite a high perception of competence. Consequently, focusing on attitudes allows for a deeper understanding of the evaluative and motivational factors that shape teachers' actions.

Furthermore, when the behavior has not yet been performed, attitude serves as a more accessible and stable indicator than self-efficacy, whose validity may be limited in the absence of prior experience. In this regard, examining teachers' attitudes toward science education offers a more comprehensive perspective for analyzing the processes of teaching and learning in science.

Ultimately, it is essential to overcome the limited attention given to teachers' attitudes, considering the influence they exert on teaching practices and, consequently, on students' scientific competence (Talavera et al., 2018).

4 Purpose of the study

In an attempt to fill this gap, this study develops and validates an instrument to measure attitudes toward teaching NoST in trainee teachers (who have experience in classroom teaching because they have taken the Practicum course) and practicing primary school teachers. We examine teachers' beliefs and emotions, and relate them to behavioral intentions when assessing different situations linked to epistemological content and the internal and external sociology of science. The instrument is conceived as a tool to assess attitudinal change after the training process. With the data collected to carry out the validation of the instrument, a first description and assessment of the attitudinal profile is also attempted.

5 Materials and methods

This study analyses the psychometric properties (Ato et al., 2013) of the scale: Attitudes toward teaching NoST in PS aimed at pre-service and in-service teachers. The objectives of this study are, therefore, to test the content and construct validity, and the reliability of the questionnaire, as well as to obtain a first description of the attitudinal profile of the participants.

5.1 Procedure

To achieve the objective of designing and validating the proposed tool, a process comprising five stages was established, as summarized in Figure 1 and detailed below. Firstly, a review of existing instruments was conducted, and an initial draft of the tool was developed based on the reviewed literature. Secondly, content validity was assessed through expert judgment. Thirdly, the length of the scale was reduced by means of item correlation analysis and a second round of expert review. Fourthly, construct validity was examined through confirmatory factor analysis and goodness-of-fit indices. Finally, the internal consistency (reliability) of the questionnaire was evaluated using McDonald's Omega coefficient. For the psychometric analysis, items related to sociodemographic variables were excluded, and the software programs Microsoft Excel, SPSS v.29, and Jamovi v.24 were used.

6 Results

This section presents the results of the different stages of the psychometric study and, in addition, the preliminary results on the attitudinal profile of the participants.

6.1 Literature review of instruments and design of the first version of the questionnaire

Initially, a series of scales were reviewed in order to analyze whether they could be applied according to the needs of the study or used as a reference. Those scales intended for students were discarded.

After the selection and review of scales aimed at teachers, several instruments were identified (Aikenhead and Ryan, 1992; Manassero et al., 2003; Rubba et al., 1996; Tyler-Wood et al., 2010; Vázquez and Manassero Mas, 1997; Villafañe and Lewis, 2016; etc.), but these were few in number and had limitations, such as the language in which they were written (predominantly English) and the non-holistic approach to the attitude object and construct (opinions toward science, attitudes toward scientific research, interest in science, etc.).

Therefore, as they did not respond to the characteristics of the study itself and the context in which it is carried out, a four-point Likert scale was designed (totally disagree, disagree, agree, strongly agree). The different items were written using the traditional method, with the criteria compiled by Morales (2000): Relevance, clarity, discrimination and bipolarity, and taking into account the three attitudinal components. The cognitive component was constructed by focusing on measuring the value, usefulness or importance that teachers attach to the discipline. These were formulated as cognitive judgments centered on the views of NoST as a discipline with value for the present and future of students. In the affective component, a series of adjectives (emotions) with a strong connotative meaning were selected to focus the measurement on the direction of emotions (positive/pleased or negative/unpleased) and their intensity (high or low polarization of the score). Emotions were selected from the Atlas de significados afectivos del español-mexicano by Urbán (1980), the taxonomy proposed by Fernández-Abascal et al. (2001), and the work of Goleman (1996). The conative component was constructed using verbal formulas that denoted intention or predisposition to perform the behaviors linked to the construct. In summary, the wording of the items was carefully designed to avoid expressions related to perceived ability or teaching competence (e.g., "I am able to...") and instead emphasized evaluative judgements, affective responses, and intentional orientations toward teaching NoST.

For the drafting of the items, reference was also made to the educational models previously analyzed: the questions of NoST according to the STS Tradition (Acevedo and García-Carmona, 2016), Project 2061 (American Association for the Advancement of Science [AAAS], 2009) and the National Research Council (1996), as they contain the appropriate topics to characterize NoST in detail. This process led to a scale of 37 items that were then submitted to expert judgment.

6.2 Content validation

For the content validity of the questionnaire, a procedure was carried out based on the judgment of three experts with recognized expertise in science education, NoST and attitudes. This number is consistent with methodological literature indicating that a small panel of highly qualified experts can provide robust qualitative validation in the early stages of scale development (Hernández-Sampieri et al., 2010). For the evaluation of the instrument, a descriptive scale was developed with four criteria (Escobar-Pérez and Cuervo-Martínez, 2008): clarity, coherence, relevance and sufficiency and four levels (with indicators) plus a section for "other comments."

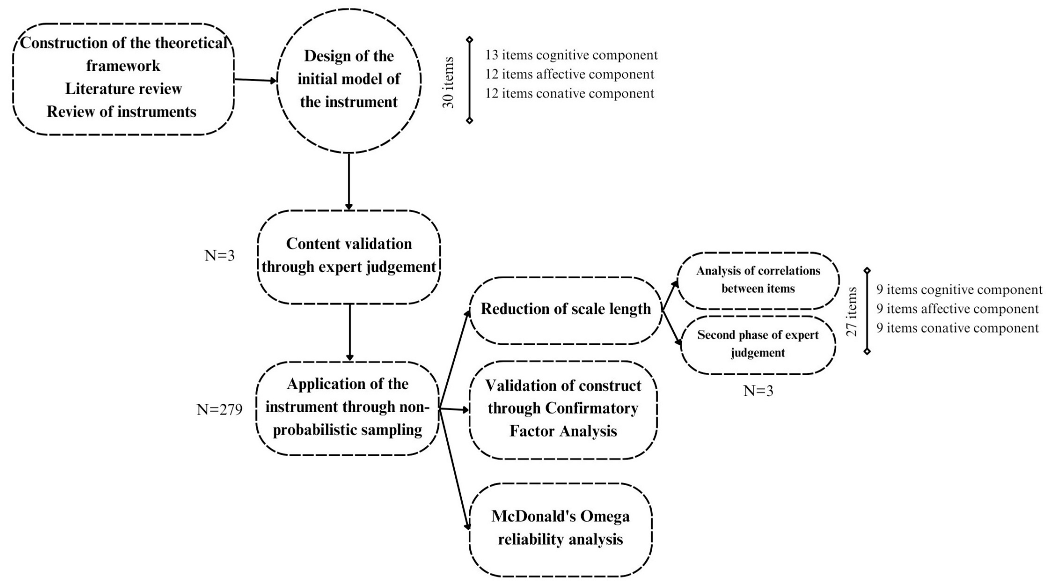

FIGURE 1
Scale design and validation process.

TABLE 1 Results of CVC.

Ítems	CVCtc	Ítems	CVCtc	Ítems	CVCtc	Ítems	CVCtc
1	0.8588	**11**	0.8380	**21**	0.8171	**31**	0.8796
2	0.9005	**12**	0.8588	**22**	0.8380	**32**	0.7963
3	0.8588	**13**	0.9005	**23**	0.7755	**33**	0.9005
4	0.8796	**14**	0.8588	**24**	0.8380	**34**	0.9005
5	0.8588	**15**	0.9005	**25**	0.8380	**35**	0.8588
6	0.8171	**16**	0.9005	**26**	0.8588	**36**	0.9213
7	0.9421	**17**	0.8171	**27**	0.9005	**37**	0.9005
8	0.8796	**18**	0.8796	**28**	0.9005		
9	0.9005	**19**	0.9005	**29**	0.8171		
10	0.8796	**20**	0.8171	**30**	0.8796		

Source: Own elaboration.

Based on the experts' evaluation, the Content Validity Coefficient (CVC) of Hernández-Nieto (2002), which indicates the degree of agreement between the judges' evaluations for each item, was calculated using Microsoft Excel.

The results obtained regarding the degree of agreement and content validity (Table 1) for the scale items indicate a predominantly excellent (>0.90) and good (>0.80 and < 0.90) level.

The feedback provided by the experts highlighted items that could be improved. Specifically, modifications were made to items 1, 4, 5, 6, 7, 11, 14, 20, 21, 22, 24, 25, 26, 31, 32, and 34 related to the clarity criterion, i.e., to improve understanding.

6.3 Scale reduction

Once the necessary modifications had been made following the expert judgment validation, the instrument was administered using two types of sampling. On the one hand, a non-probabilistic snowball sampling method was employed, given that the target population was small and specialized. On the other hand, an accidental/convenience non-probabilistic sampling approach was used, as the selected sample consisted of student groups to which the researchers had access. In total, the instrument was administered to 219 Spanish-speaking participants.

Based on the results obtained from this pilot test, the scale was reduced through a Spearman correlation analysis between items. Items that did not show significant correlations with the others were submitted to a second round of expert judgment in order to assess the relevance of their removal. This decision was based on both the statistical outcome (which indicates whether the items are measuring the same dimension or diverging into unrelated aspects) and relevant literature in the field. As a result of this process, the scale was reduced from 37 to 27 items (Table 2). The Spanish version can be found in Table A1.

TABLE 2 Questionnaire items and dimensions in brackets.

F1. Component cognitive
1. I believe that experiencing how scientists think and act (observe, classify, ask questions, construct explanations, communicate ideas) is important for students to acquire a scientific culture applicable to their lives (EPIS). 2. In my opinion, science education allows students to face error positively or accept different opinions (EPIS). 3. I think it is not important to teach students to generate or evaluate arguments on scientific issues (EPIS). 4. It seems to me that science is a complex knowledge. Children cannot understand that science is knowledge that entails social, political and economic changes, only the scientific community is capable of understanding it (ES). 5. I believe that scientific culture is relevant for students to understand their environment (ES). 6. In my opinion, the teaching of science in Primary Education allows students to understand how cultural values or prejudices influence science, technology and society (ES). 7. I think it is important to include in science proposals activities to dismantle stereotypes of scientists (IS). 8. In my opinion, it is useful for students to learn how scientists work in teams or communicate (IS). 9. I believe that it is not necessary to claim the role of women or minorities in science in the Primary Education classroom (IS).
F2. Component affective
10. I am afraid to introduce activities in the classroom so that students learn to answer scientific questions by combining procedures such as observation or experimentation with the search for information (EPIS). 11. Teaching my students to plan, carry out and evaluate simple research gives me satisfaction (EPIS). 12. I am happy to teach my students how to use data to construct a reasonable explanation for a phenomenon (EPIS). 13. I am happy to introduce activities in the classroom that encourage learning about how societal challenges or priorities inspire or influence research questions or technological development (ES). 14. It makes me insecure to have to teach students what the values or prejudices of culture include in science (ES). 15. I am overwhelmed by introducing activities in the classroom about the evolution of science, technology and society throughout history (ES). 16. I am anxious to introduce activities in the classroom so that students understand that the scientific community is diverse (IS). 17. Carrying out activities for students to understand the underrepresentation of women and minorities in science brings me joy (IS). 18. I don't like working with my students on the objectives of communication in the work of scientists (IS).
F3. Component conative
19. I intend to teach my students to plan, carry out and evaluate simple research (EPIS). 20. I am willing to teach my students to use data to construct a reasonable explanation for a phenomenon (EPIS). 21. I do not intend to carry out activities in my classroom where students have to identify a problem and select or build an analog (e.g., binocular magnifier) or digital (e.g., laptop) tool (EPIS). 22. I am willing to teach my students that technological changes bring about social, political, and economic changes that can be beneficial or detrimental (ES). 23. I'm not going to teach my students to understand how cultural values or biases influence science (ES). 24. I am willing to introduce activities in the classroom on the evolution of science, technology and society throughout history (ES). 25. I will carry out activities so that students understand that the scientific community is diverse (different types of people, jobs, places or times) (IS). 26. It is likely to carry out activities to make students understand the underrepresentation of women and minorities in science (IS). 27. It is unlikely that I will work with my students on the objectives of transfer in the work of scientists (sharing ideas, making decisions, communicating results, planning the work...) (IS).

Source: Own elaboration. EPIS, epistemology; ES, external sociology; IS, internal sociology.

6.4 Construct validity

To assess the construct validity of the questionnaires, a Confirmatory Factor Analysis (CFA) was performed using the SEM (Structural Equation Modeling) package (Gallucci and Jentschke, 2021; Rosseel et al., 2019) in Jamovi v.24. This type of analysis was chosen because, as previously mentioned, the scales were developed based on a theoretically pre-established structure derived from the literature on the attitude construct. Consequently, the resulting path diagram (Figure 2) reflects a hierarchical model in which a second-order factor represents the overall attitude, expressed through its three components: cognitive, affective, and conative. These components, although distinct, converge strongly due to a shared foundation (i.e., the representation of the same underlying attitude) among individuals with consistent attitudinal profiles.

The factor loadings reveal that, in general, the relationship between observed variables and latent factors is both statistically significant and consistent, with most loadings being moderate ($\geq$0.50) or strong ($\geq$0.70). This suggests that the model's structure is appropriate. For those items with lower factor loadings, their inclusion was deemed conceptually relevant by the experts involved in the second round of expert judgment. These items provide meaningful insights into the construct and help maintain balance across the different aspects represented (epistemology, internal sociology, and external sociology). For example, removing item 15 would result in a loss of valuable information concerning the affective dimension of teaching's external sociology.

Model fit indices were analyzed (Table 3) to determine whether the proposed models fit the data satisfactorily. The Robust Weighted Least Squares estimator (WLSMV) was used, as it does not assume normality of variables and is especially suitable for CFAs with dichotomous or ordinal data (Xia, 2016). This estimator corresponds to a robust correction of DWLS. The interpretation of the results was based on scaled indices. First, absolute fit indices were considered: root mean square error of approximation (RMSEA), standardized root mean square residual (SRMR), and chi-square (χ^2). Second, incremental fit indices were examined: comparative fit index (CFI), normed fit index (NFI), and Tucker–Lewis index (TLI). Third, parsimonious fit was assessed using the parsimonious normed fit index (PNFI).

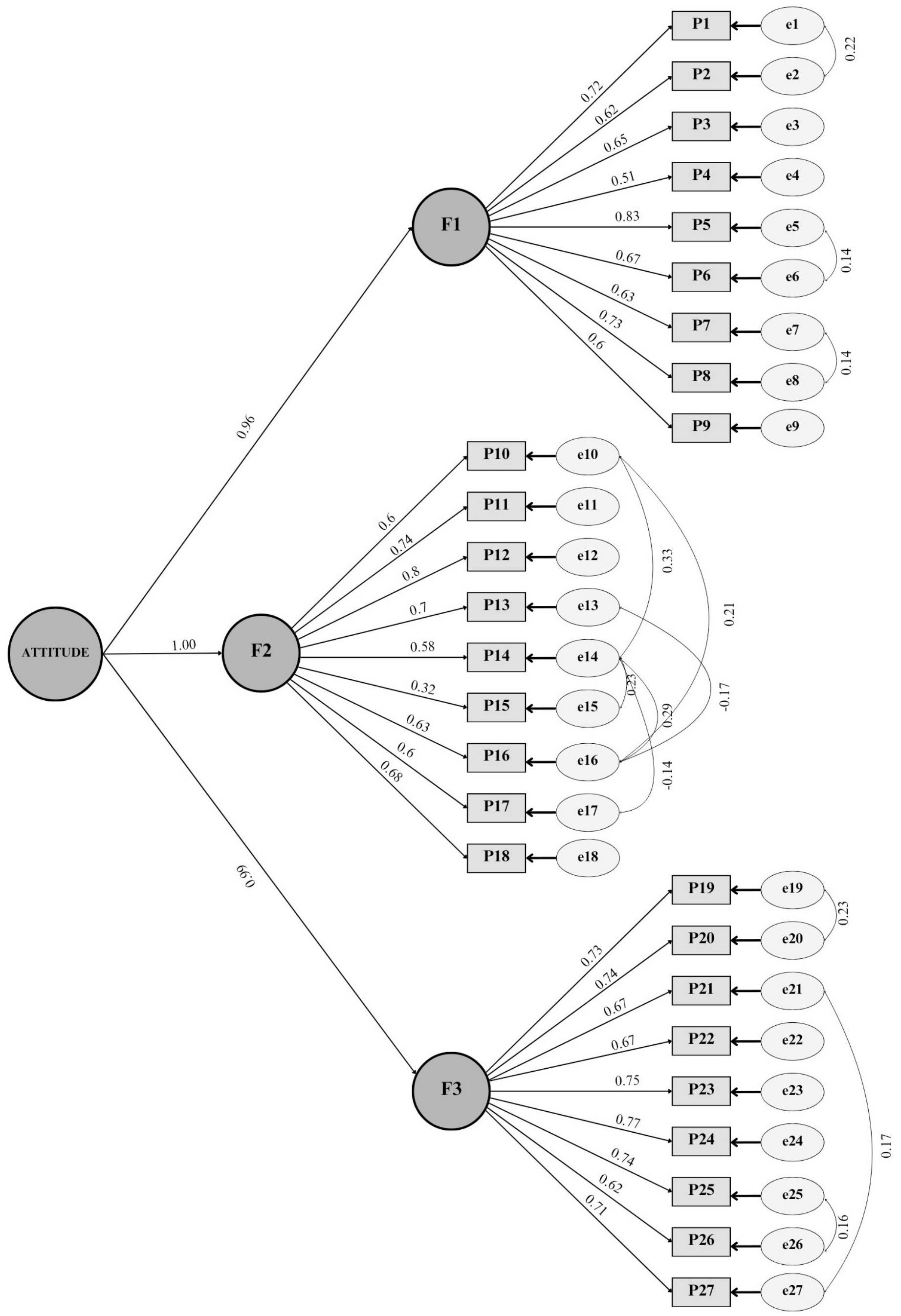

FIGURE 2
Path diagram.

TABLE 3 Results of the maximum likelihood parameters.

Absolute fit measurement			Incremental adjustment measures				Parsimony adjustment measures
RMSEA	SRMR	χ^2 (df)	CFI	TLI	NFI	GFI	PNFI
0.08	0.07	987 (309)	0.93	0.92	0.90	0.98	0.80

Source: Own elaboration.

Analysis of the data indicates that the proposed models, after certain modifications (removal of non-significant paths and addition of correlations between residuals), display an adequate fit. Absolute fit indices show acceptable values for this type of model, with RMSEA $\leq$ 0.08, SRMR $<$ 0.08, and a χ^2/df ratio close to 3 (Browne and Cudeck, 1993; Cho et al., 2020; West et al., 2012).

Similarly, the incremental fit indices (CFI, TLI, NFI, and GFI) yielded values considered acceptable ($\geq$0.90) and optimal ($\geq$0.95), according to specialized literature (Bentler, 1990; Hu and Bentler, 1999; Cho et al., 2020; Lai, 2020; Xia and Yang, 2019).

Finally, in terms of parsimony, the PNFI showed appropriate values, approaching 0.80 (Byrne, 2001; Hu and Bentler, 1999).

In summary, after making adjustments to the model, the results indicate a good fit to the data. Model modifications were implemented following a theory-informed approach. Modification indices were considered only when they were conceptually coherent with the multidimensional attitudinal framework and with established interpretations of NoST-related dimensions. No modifications were introduced that altered the underlying theoretical structure of the model. The various indices used to assess model quality support the consistency and stability of the proposed relationships, thereby confirming the validity of the scale's underlying structure.

6.5 Internal consistency

To assess the internal consistency of the questionnaire, reliability was analyzed using McDonald's Omega coefficient (McDonald, 1999), in order to overcome the limitations associated with Cronbach's alpha and to obtain more stable estimates (Ventura-León and Caycho-Rodríguez, 2017). The McDonald's Omega value calculated for the scale was 0.96. The conclusion from this result is that the scale demonstrates high reliability (Campo-Arias and Oviedo, 2008).

6.6 Preliminary results

As previously indicated, the analysis of the scale was complemented by an examination of the preliminary results obtained through its application. For this purpose, SPSS v.29 was used. This software was employed to compute descriptive statistics for the attitudinal components and for the overall scale. Additionally, comparisons were made based on selected sociodemographic variables (gender, academic/employment status, age, and experience).

Since the Kolmogorov–Smirnov test yielded a p-value of 0.003, indicating that the data did not follow a normal (Gaussian) distribution, and given the ordinal nature of the variables, non-parametric statistical tests were applied: the Mann–Whitney U test for comparisons between two independent groups, and the Kruskal–Wallis H test for comparisons among several independent groups. Effect size (r) was also calculated to assess the strength of the relationships. Furthermore, Spearman's rank correlation coefficient was used to analyze the relationship between attitudinal components and to assess the external criterion validity of the scale.

6.6.1 Results of the attitude scale toward teaching NoST in Primary Education

The overall attitude toward teaching NoST in the primary classroom can be considered to be positive, given that the mean score was 92.21 points (SE = 0.166), with 27 and 108 being the minimum and maximum possible scores, respectively.

Measures of position identify three distinct profiles. 50% of the sample expressed positive opinions or beliefs, scoring between 28 and 34 points. 25% showed highly positive attitudes, with scores above 34, while the remaining 25% exhibited negative opinions, scoring below 28.

With regard to the attitudinal components, these were found to behave similarly. As the minimum and maximum values for the cognitive, affective, and conative components ranged from 9 to 36 points, the mean scores indicate that participants considered the subject matter to be highly important or useful (M = 31.03; SE = 3.743), generally expressed positive affect toward teaching NoST (M = 30.43; SE = 4.125), and demonstrated a high behavioral intention to include NoST content in their classrooms (M = 30.75; SE = 3.927).

6.6.2 Results of the relational analysis between attitude components

The results compiled in Table 4 regarding Spearman's correlation reveal that there is a systematic relationship between the attitude components. They are linearly, directly and highly significantly related. Positive affect is linked to high behavioral intention and favorable beliefs toward the object.

6.6.3 Results of attitudes toward teaching NoST according to gender, academic/employment status, age, and teaching experience

In order to explore potential significant differences in the study results based on the sociodemographic variables considered (gender, age, teaching experience, and academic/employment status), a comparative analysis was conducted across the different groups defined by these variables. As shown in Table 5, statistically significant differences were found only in relation to age.

7 Discussion and conclusion

From a practical perspective, the validated instrument presented in this study can be used in both initial and in-service teacher education to diagnose attitudinal profiles, monitor changes following professional development or training programs, and identify specific dimensions that require targeted support. Conceived as a diagnostic and evaluative tool, the scale allows for the assessment of attitudinal change and the effectiveness of educational and classroom interventions. This focus is especially relevant in teacher education, as attitudes play a key role not only in teachers' personal and professional development, but also in shaping future teaching practices and influencing students' own attitudes toward science.

The construction of the scale took into account several psychometric challenges in attitude measurement within science education, as identified in the literature. To avoid deficiencies in reliability and validity stemming from poor definitions of the constructs involved (science and attitudes) (Vázquez and Manassero, 1995), a theoretical framework was developed that considers attitudes from the perspective of Social Psychology—providing an appropriate foundation of basic theories (Vázquez and Manassero, 1995)—and science from the metacognitive perspective of NoST. This approach addresses key innovations in science teaching and learning, clarifies the object of the attitude (Bogdan and Meneses, 2021), makes its multidimensionality

TABLE 4 Results of the correlational factor analysis.

		C. Cognitive	C. Affective	C. Conative
C. Cognitive	Spearman correlation	1	0.767**	0.767**
	Sig. (bilateral)		< 0.001	<0.001
C. Affective	Spearman correlation		1	0.818**
	Sig. (bilateral)			< 0.001
C. Conative	Spearman correlation			1
	Sig. (bilateral)			

Source: Own elaboration. **Highly significant correlation.

TABLE 5 Results of the hypothesis testing.

Variable		Mean	SD	Mann-Whitney			
				U	*p*	*Z*	*r*
Academic/employment status	In service (*N* = 135)	92,251	10,807	4,390	0.612	−0.507	−0.03
	In training (*N* = 68)	93,8667	8,919				
Gender	Woman (*N* = 162)	92,724	10,728	30,105	0.488	−0.694	−0.05
	Man (*N* = 40)	90,772	10,267				
Variable		**Mean**	**SD**	**Kruskall-Wallis**			
				H	*p*		
Age	18–24 years (*N* = 59)	93,666	8,853	10,065	0.039		
	25–34 years (*N* = 38)	90,310	9,320				
	35–44 years (*N* = 39)	90,897	12,113				
	45–54 years (*N* = 42)	91,357	11,237				
	55–64 years (*N* = 25)	98,240	7,584				
Teaching experience	One prácticum (*N* = 56)	89,636	9,036	11,334	0.125		
	1–5 years (*N* = 24)	89,5	9,055				
	6–10 years (*N* = 20)	93,1	10,315				
	11–15 years (*N* = 21)	88,761	12,723				
	16–20 years (*N* = 24)	91,742	10,478				
	21–25 years (*N* = 21)	91,857	11,069				
	> 25 years (*N* = 15)	90,127	10,060				

Source: Own elaboration.

explicit (Manassero Mas and Vázquez, 2002), and promotes affective aspects not merely as a means to improve learning but as educational content in their own right (Vázquez and Manassero Mas, 1997).

The structure of the tool includes three factors, which add value given that existing literature does not treat the construct holistically, with a prevailing emphasis on the cognitive component (García-Marigómez et al., 2026).

First, one subdimension gathers evidence regarding beliefs and opinions on the relevance of teaching NoST in Primary Education. Literature has predominantly focused on evaluating the correctness of opinions on scientific issues (Barnes et al., 2015; Ozturk-Akar and Dogan, 2013; Yalvac et al., 2007), but has largely ignored perspectives on the importance of including these topics in the classroom.

Second, the emotional component related to such teaching is addressed, given the relevance and impact of emotions in teaching practice. While studies focusing on affectivity toward teaching NoST are lacking, existing research by Aguirregabiria and García-Olalla (2022), Clerici (2008), Kaya et al. (2009), Mateos Núñez and Martínez Borreguero (2021), and Martínez-Borreguero et al. (2022) shows a predominance of negative emotions toward science topics, highlighting the need to strengthen affective connections to achieve genuine commitment to meaningful science teaching.

Lastly, the predisposition toward teaching is included as a factor, recognizing the potential of attitudes to predict behavior (Ajzen and Fishbein, 1980; Hogg and Vaughan, 1995) and to better understand the attitude-behavior relationship. This component represents a significant contribution, as no previous studies were found addressing this variable. In existing literature, behavioral intention has been primarily explored in the context of students' intentions to pursue science-related careers (Roberts, 2014).

The scale therefore helps fill a gap in the literature regarding tools that assess attitudes comprehensively. It also addresses other gaps, such as the limited focus on teachers, teaching, and NoST as central elements in the educational process.

Additionally, the scale's structure allows for a global understanding of attitudes and how the different components interrelate, supporting the search for strategies that promote attitudinal—and therefore pedagogical—change. A more detailed item-by-item analysis may reveal which science topics are associated with more positive or negative attitudes.

After the favorable results from the content validity assessment by expert judges it was possible to proceed with construct validity and internal consistency analysis. Again, positive results from the CFA and McDonald's omega supported the instrument's alignment with the theoretical model and its high reliability. The scale's psychometric consistency enables robust evaluation of an essential but often overlooked competence: knowing how to be in science teacher education. No comparison was made with other instruments due to the lack of similar or comparable characteristics, as the study addresses a previously identified gap in the literature.

Given the original and novel nature of this study, no direct comparison can be made with previous work. However, connections with literature on other attitudinal aspects related to teachers provide valuable considerations.

Results regarding attitudes toward teaching NoST indicate a generally positive trend. However, this conclusion is based on descriptive statistics reflecting general patterns. Future studies should apply more detailed analyses to identify attitude profiles, enabling more targeted and effective educational interventions. Moreover, while the results indicate generally positive attitudes toward teaching NoST, the present study does not allow direct conclusions to be drawn regarding actual classroom implementation. Any potential discrepancy between attitudes and practice should therefore be interpreted with caution and constitutes an important avenue for future research rather than a conclusion derived from the current data.

At the cognitive level, the findings suggest that teachers value NoST as important and useful for Primary Education, despite existing studies showing their views on these topics are often naive or inadequate (Barnes et al., 2015; Ozturk-Akar and Dogan, 2013; Yalvac et al., 2007).

On the emotional level, the emotions reported are predominantly positive, in contrast to earlier studies (Aguirregabiria and García-Olalla, 2022; Clerici, 2008; Kaya et al., 2009; Mateos Núñez and Martínez Borreguero, 2021; Martínez-Borreguero et al., 2022; Murphy and Smith, 2012), which reported negative feelings toward science content.

Regarding the conative component, reported scores show a high predisposition. As mentioned before, no previous studies have focused specifically on this construct.

These findings underscore the need to explore why a predominantly positive attitude toward teaching NoST does not translate into its actual inclusion in the classroom (Acevedo, 2009; De Pro et al., 2022; García-Marigómez et al., 2026). Links must be established between this gap and obstacles identified in the literature, such as limited knowledge (Walag et al., 2022), low self-efficacy (Clerici, 2008; Murphy and Smith, 2012), and the persistence of traditional teaching practices (Aragón Núñez, et al., 2021; Kim and Tan, 2011; Mansour, 2013). Understanding these connections will help design training approaches that address both cognitive and affective factors hindering educational transformation in science teaching.

7.1 Limitations and future directions

Among the main limitations identified is, firstly, the sample size and its non-probabilistic nature. A larger and more diverse sample (both in terms of participants and schools) would yield more robust results across the different phases of statistical analysis. Regarding its non-random nature, it is worth noting that such sampling is common—and often the only feasible option—in educational research, due to practical and contextual constraints.

Secondly, since the instruments were self-administered, there is an increased risk of response bias, which may affect the accuracy of the data collected.

Thirdly, the instrument was designed and adapted for Spanish-speaking contexts, meaning its applicability in other settings cannot be guaranteed without prior translation and cultural adaptation to ensure validity and reliability.

Fourthly, although reducing the length of the questionnaire was necessary to avoid excessive burden, this limited the ability to explore the construct in greater depth and detail.

Finally, it is important to note that this instrument is not used in isolation but forms part of a broader methodological framework involving multiple tools aimed at gaining a deeper understanding of the complex nature of attitudes and avoiding the limitations of a purely positivist perspective in educational research.

Looking ahead, future research could involve expanding the sample size once the scale is fully validated, in order to obtain more conclusive results.

Applying the instrument in various educational programs could help analyze its potential and support further research based on educational interventions. This research should include longitudinal designs to examine attitude change over time, studies exploring the relationship between attitudinal components, and studies investigating the connection between teachers' attitudes and actual classroom practices.

In addition, cross-cultural validation of the instrument in different educational contexts may be of interest.

Data availability statement

The datasets presented in this article are not readily available due to confidentiality restrictions and data embargo, as the research is still in progress. Requests to access the datasets should be directed to carmela.garcia@uva.es.

Ethics statement

The study involving human participants was approved by the Ethics Committee of the University of Valladolid. Furthermore, the study guaranteed the confidentiality and anonymity of the research participants. The management and processing of the data were carried out in accordance with Organic Law 3/2018, of December 5, on the Protection of Personal Data and Guarantee of Digital Rights, and Regulation (EU) 2016/679 of the European Parliament and of the Council of April 27, 2016, on the protection of natural persons with regard to the processing of personal data and the free movement of such data, repealing Directive 95/46/EC (General Data Protection Regulation). The participants gave their express consent and were also informed of the study's objective and their right to withdraw at any time. Their participation was voluntary. The study was conducted in accordance with local legislation and institutional requirements. The participants provided their written informed consent to participate.

Author contributions

CG-M: Writing – original draft, Formal analysis, Funding acquisition, Methodology, Data curation, Investigation, Writing – review & editing, Conceptualization, Software. VO-Q: Investigation, Writing – review & editing, Supervision, Methodology, Writing – original draft, Resources, Visualization, Software. CG-P: Supervision, Conceptualization, Funding acquisition, Project administration, Writing – review & editing, Validation, Writing – original draft.

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Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Appendix

Table A1 Ítems del cuestionario y dimensiones entre paréntesis.

F1. Componente cognitivo
1. Considero que experimentar cómo los científicos y las científicas piensan y actúan (observar, clasificar, formular preguntas, construir explicaciones, comunicar ideas. . .) es importante para que el alumnado adquiera una cultura científica aplicable a su vida (EPIS).
2. A mi parecer, la educación científica permite al alumnado afrontar positivamente el error o aceptar opiniones diferentes (EPIS).
3. Creo que no es importante enseñar al alumnado a generar o evaluar argumentos sobre cuestiones científicas (EPIS).
4. Me parece que la ciencia es un saber complejo. Los/as niños/as no pueden entender que la ciencia es un saber que conlleva cambios sociales, políticos y económicos, solo la comunidad científica es capaz de comprenderlo (SE).
5. Creo que la cultura científica es relevante para que el alumnado pueda comprender su entorno (SE).
6. A mi parecer, la enseñanza de las ciencias en Educación Primaria permite al alumnado comprender cómo los valores o prejuicios culturales influyen en la ciencia, la tecnología y la sociedad (SE).
7. Me parece importante incluir en las propuestas de ciencias actividades para desmontar los estereotipos de los/as científicos/as (SI).
8. En mi opinión, que el alumnado aprenda cómo los/as científicos/as trabajan en equipo o se comunican es útil (SI).
9. Considero que no es necesario reivindicar el papel de las mujeres o minorías en la ciencia en el aula de Educación Primaria (SI).
F2. Componente afectivo
10. Me causa miedo introducir en el aula actividades para que el alumnado aprenda a responder cuestiones científicas combinando procedimientos como la observación o experimentación con la búsqueda de información (EPIS).
11. Enseñar a mi alumnado a planificar, realizar y valorar una investigación sencilla me provoca satisfacción (EPIS).
12. Me alegra enseñar a mis estudiantes a usar datos para construir una explicación razonable sobre un fenómeno (EPIS).
13. Me alegra introducir en el aula actividades que fomenten el aprendizaje sobre cómo los retos o prioridades sociales inspiran o influyen en las preguntas de investigación o en el desarrollo tecnológico (SE).
14. Me produce inseguridad tener que enseñar a los y las estudiantes que los valores o prejuicios de la cultura incluyen en la ciencia (SE).
15. Me agobia introducir en el aula actividades sobre la evolución de la ciencia, la tecnología y la sociedad a través de la historia (SE).
16. Me angustia introducir en el aula actividades para que los y las estudiantes comprendan que la comunidad científica es diversa (SI).
17. Realizar actividades para que el alumnado comprenda la infrarrepresentación de mujeres y minorías en la ciencia me causa alegría (SI).
18. Me desagrada trabajar con mi alumnado los objetivos de la comunicación en el trabajo de los/as científicos/as (SI).
F3. Componente conativo
19. Tengo intención de enseñar a mi alumnado a planificar, realizar y valorar una investigación sencilla (EPIS).
20. Estoy dispuesto a enseñar a mis estudiantes a usar datos para construir una explicación razonable sobre un fenómeno (EPIS).
21. No tengo intención de realizar actividades en mi aula donde el alumnado tenga que identificar un problema y seleccionar o construir una herramienta analógica (p.ej: lupa binocular) o digital (p.ej: portátil) (EPIS).
22. Estoy dispuesto a enseñar a mis estudiantes que los cambios tecnológicos conllevan cambios sociales, políticos y económicos que pueden ser beneficiosos o perjudiciales (SE).
23. No voy a enseñar a mis estudiantes a comprender cómo los valores o prejuicios de la cultura influyen en la ciencia (SE).
24. Estoy dispuesto a introducir en el aula actividades sobre la evolución de las ciencias, la tecnología y la sociedad a través de la historia (SE).
25. Voy a realizar actividades para que los/as estudiantes comprendan que la comunidad científica es diversa (diferentes tipos de personas, trabajos, lugares o épocas) (SI).
26. Es probable que realice actividades para que el alumnado comprenda la infrarrepresentación de mujeres y minorías en la ciencia (SI).
27. Es poco probable que trabaje con mi alumnado los objetivos de la transferencia en el trabajo de los/as científicos/as (compartir ideas, tomar decisiones, comunicar resultados, planificar el trabajo. . .) (SI).

Fuente*:* Elaboración propia. EPIS, epistemología; SE, sociología externa; SI, sociología interna.