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ARTICLE

Multivariate Analysis of Beliefs in Pseudoscience and Superstitions Among Pre-service Teachers in Spain

Remo Fernández-Carro[1] · **José Eduardo Vílchez**[2] · **José Miguel Vílchez-González**[3] · **Ángel Ezquerra**[4]

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Abstract

Do pre-service teachers have the same beliefs in superstitions and pseudoscience as the members of their generation? We expect so, because they are slightly different in at least two of the variables that explain differences, namely family income and level of studies, and also, normatively, because beliefs among teaching staff appear to be a key matter in the scientific literacy of citizens. Research reported in this paper compared data from the general public of the same age to our sample of 578 pre-service teachers from five Spanish universities, using the same questionnaire. Multivariate regression analysis is then used to study the factors that affect defence of such beliefs and the differences between pre-service teachers and their age group. We have found that, on the contrary to what was expected, beliefs among pre-service teachers are not far from those of their age group in the population at large. Within that relatively homogenous group, a favourable attitude toward pseudoscience and superstition mainly depends on their educational level and basic knowledge of science, but that knowledge probably depends on their spontaneous interest in scientific matters and a prior favourable attitude. These results have implications in training scientific teachers and in the scientific literacy of the population. Thus, we must consider such non-scientific beliefs when designing classroom proposals and when communicating scientific content in social contexts.

✉ Remo Fernández-Carro
joseremo.fernandez@uclm.es

[1] Department of Philosophy, Anthropology, Sociology and Aesthetics, Universidad de Castilla-La Mancha, Cuenca, Spain

[2] Centro de Estudios, Universitarios Cardenal Spínola CEU, Seville, Spain

[3] Department of Science Education, Universidad de Granada, Granada, Spain

[4] Department of Science, Social Science and Mathematics Education, Universidad Complutense de Madrid, Madrid, Spain

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1 Introduction

Knowledge *of* science and *about* science that the citizens need to make decisions in daily contexts is known as scientific literacy. Development and implementation of this concept constitutes one of the objectives of scientific education (Bybee, 1991; DeBoer, 2000; Feinstein, 2011; Hodson, 2003). This is recognised by bodies such as the UNESCO (1999) or the European Commission (EC, 2007), international evaluations such as PISA (OECD, 2019a, b), or Eurobarometers 224 and 401 (European Commission [EC] 2005, 2013). In the Spanish context, we find the report by the Confederation of Scientific Societies of Spain (COSCE, 2011) or Surveys regarding the Social Perception of Science and Technology of the Spanish Foundation for Science and Technology (FECYT, 2019), biannual since 2003. All that information is allowing us to ascertain the existing level of scientific knowledge, the perception and attitude society has toward science and technology, and how these factors have gradually evolved. The concern and interest shown in these reports is also recorded in the legislative frameworks of nearly all European school curricula (COSCE, 2011).

It does not appear to be simple to determine what the desirable levels of scientific literacy are (Bybee, 1997; Shen, 1975); in fact, there is not even consensus on how to set these levels (Cortassa, 2016; Wynne, 1995; Yearley, 1994) nor the necessary means to achieve these. However, citizens are usually bound to interact with science and technology in their daily activities and to deal with socio-scientific issues (Ezquerra et al., 2017).

There are many factors that influence the citizen's situation regarding decision-making on scientific matters. A group that plays a major role is science teaching staff. They have the responsibility for encouraging their students to develop the abilities required to confront relevant socio-scientific issues in our society (Doygun et al., 2019; Feinstein et al., 2013; Hodson, 2011). This means the teaching staff must be attentive, at least to the following matters: (1) knowing the socio-scientific issues in our society, (2) understanding the role played by science in our society (Lederman, 1999), (3) knowing how science is perceived by our society, (4) identifying which socio-scientific issues are most relevant for the students at each educational level (Albe, 2008), (5) identifying perception of science among students (Kolstø, 2006; Lewis & Leach, 2006; Zeidler et al., 2002), (6) reflecting on the perception the teachers have of science and Nature of Science (NoS) (García-Carmona & Acevedo Díaz, 2016), and (7) determining the most adequate teaching style for the students to develop abilities to engage in reasoned discussion and to make decisions (Levinson, 2006). This set of actions implies that the teaching staff must develop specific knowledge and skills regarding existing science in society and the way in which it is seen by the students and faculty. On the other hand, studies in Public Understanding of Science (PUS) show us that advanced societies show general support for science but with nuances. They also warn us that the attitude a person has to science depends little on their level of scientific knowledge (Bak, 2001; Wynne, 1995). We may find both groups that back it without knowing it, even without having a great interest in it, as well as others who know it well and support it. Likewise, we may find groups that reject it independently of their level of knowledge. Reluctant acceptance is greater among those with higher qualifications, although it arises in all social groups (Michael, 1992). Meanwhile, other persons who reject a specific aspect of science—those who reject the theory of evolution or vaccination, for example—may display a deep knowledge of the disciplines or theories they reject (Rozbroj et al., 2019).

Similarly, those who defend pseudoscience or superstitions are not necessarily people who reject or ignore science (Astin, 1998; Kemppainen et al., 2018). Paradoxically, pseudoscience (homoeopathy or quantum healing, for example) is accepted by groups that reject superstitions (palmistry and fortune-telling, among others). It appears that each group tends to accept certain pseudo-beliefs and reject others. Pseudosciences have a social value for the social groups that support them, beyond their real utility (Rayner & Easthope, 2001).

The explanation is more complex than mere credulity, lack of culture, or vulnerability to deceit (Rozbroj et al., 2019; Ballová Mikušková, 2018; Genovese, 2005). We know that education does not fully protect us from pseudoscience (Ballová Mikušková, 2018; Eve & Dunn, 1990), not even scientific education, even at high standards such as PhD level. The response lies in the way in which knowledge is received through groups of relatives or friends or the way in which such groups provide them status (Rayner & Easthope, 2001).

We are concerned that beliefs in pseudoscience and superstitions may compromise the functions and skills that have been mentioned and that science teachers must develop to contribute to scientific literacy among the population. Future teachers belong to social groups with higher studies and intermediate revenue (Astin, 2000; Cano-Orón et al., 2019; Eisenberg et al., 1998; Fjær et al., 2020; Rozbroj et al., 2019; Thomas et al., 2001), that is, just those who do not consider it a contradiction to support science and maintain belief in homoeopathy or acupuncture.

On the other hand, it is known that not all the teaching staff have a good knowledge of the way in which science works (Lederman, 1999), are not able to integrate advances in NoS in the classroom in a desirable manner (Vázquez-Alonso et al., 2013), nor do they identify the demarcation between scientific knowledge and what is not (Boudry et al., 2015; Pigliucci & Boudry, 2013). One may partially transmit inadequate ideas to their students regarding science (Eve & Dunn, 1990; Fuertes-Prieto et al., 2020; Genovese, 2005). Thus, the interest in knowing how the teachers perceive pseudoscience and superstitions.

Research in science education has approached study of pseudoscience and superstitions from various points of view. Thus, we can find articles that explore the potential in the use of such beliefs as a resource to devise activities which help students to understand how NoS works (e.g. Schmaltz & Lilienfeld, 2014; Southerland et al., 2012) and work that analyses beliefs regarding pseudoscience and superstition among students at diverse educational stages (e.g. Preece & Baxter, 2000; Tseng et al., 2014) with qualitative approaches (Kaplan, 2014) and quantitative ones (Çekbaş & Çokadar, 2015; Fuertes-Prieto et al., 2020; Losh & Nzekwe, 2011; Solbes Matarredonda et al., 2018).

This work inquires if pre-service teachers have the same beliefs in superstitions and pseudoscience than their generation and, if this is the case, to what extent. Then it asks whether common explanatory variables have the same influence the same way. We hypothesise that the two groups differ, as we have explained; pre-service teachers should believe slightly less in superstitions and pseudoscience.

We consider the following research objectives: (1) to identify pre-service teacher beliefs in pseudoscience and superstition and to compare them with the population of the same age and (2) to identify the factors involved in those patterns. Specifically, in this article, we delve into the differences between future teachers and their age group and some of their possible causes, through multivariate regression analysis.

2 Methodology

In order to respond to these matters, we compare the data of our survey *Percepción de la Ciencia y la Tecnología entre Maestros en Formación* (PCYTMF, Perception of Science and Technology Among Pre-Service Teachers) with those of the Social Perception of Science and Technology Perception (EPSCYT) survey of 2016 by the Spanish Foundation for Science and Technology (FECYT, 2017), of which it is a replica.[1] The main analytical method used was ordinary least squares regressions (OLS) in which the dependent variable is a result of a previous factor analysis of question P15. The purpose is to provide an explanatory analysis, but the work begins with a descriptive one.

2.1 Participants and Context

Five hundred seventy-eight university students answered the survey. Four hundred eighty-five of them were teacher trainees enrolled in preschool (84, 14.5%), primary (306, 52.9%), and secondary (95, 16.4%).[2] Ninety-three more students were enrolled in related degrees, such as Pedagogy. All these degrees are 4 years long except the one for secondary education teacher that is a 1-year master in pedagogical contents and hold a 4-year degree as a requirement.

The sample is taken from five Spanish universities (Complutense University of Madrid, University of Castilla-La Mancha, Centro Cardenal Spínola CEU, Seville, University of Granada, and University of Castilla-León). The sample is not a statistically representative random one. Although a convenience sample, it involves an ample geographic distribution and socio-demographic differences (different regions, different sizes of city, different socio-economic levels, different university types, public or private) which makes it relatively representative of the universe of Spanish pre-service teachers. Early in the elaboration, we found that clustering did not change the results, so we have not used hierarchical models.

2.2 Description of the Variables and Their Transformations

2.2.1 Identification with Different Beliefs (Dependent Variable)

The dependent variable is an elaboration of the battery P15 of PCYTMF (see the items in Table 1), which is P26 of EPSCYT. P15 data were reduced using factor analysis—of principal components with varimax rotation and retaining factor analysis scores through the regression method. The factor represents how much each individual believes in these secular beliefs. In a similar study applied to the general public, Santos-Requejo et al. (2017) found two factors instead of one, *superstitions* and *pseudoscience* (we follow their wording). This implies that society distinguishes between types of beliefs and there are groups of people who provide them different values. Our factor analysis indicated that our students

[1] For the differences between PCYTMF and the original EPSCYT, see Annex 1.

[2] Education levels in Spain are preschool (*Infantil*, 3–6 years), primary (*Primaria*, 6–12, compulsory), and the secondary, which is split in compulsory (*Educación Secundaria Obligatoria*, *ESO*, 12–16 years) and non-compulsory (*Bachillerato*, 16–18 years). The University is generally accessed from the age of 18.

Table 1 Identification with different secular beliefs, question 15 (P15) of PCYTMF

	"Please tell us if you identify with any one of the following statements: Do you identify **very little, some, quite, much, or very much** with what is stated"?					
	Valid percentages	Very little	Some	Quite	Much	Very much
P15.1	*I believe in paranormal phenomena*	35.8	24.0	20.9	12.5	6.7
P15.2	*Acupuncture works*	19.7	26.5	31.1	17.1	5.6
P15.3	*What horoscopes predict happens*	53.8	21.5	17.3	5.5	1.9
P15.4	*Homoeopathic products are effective*	34.7	24.4	27.4	11.6	1.9
P15.5	*I trust healers*	53.6	24.7	14.2	5.5	1.9
P15.6	*Lucky numbers and things exist*	38.0	22.5	21.0	14.0	4.5

do not seem to make that distinction (also see Fuertes-Prieto et al., 2020). That is, our sample is more homogeneous in that regard.

2.2.2 Knowledge 23

The knowledge of science could produce a positive attitude toward science and technology, although it is *not always* the case, as we have seen: the two questions regarding scientific culture, here P14 and P16, are designed for the purpose of measuring scientific culture (see Annex 1). P14 is a battery of eight items; it is usually called the "Oxford questionnaire", and it is repeated often due to its efficiency and comparability, measuring scientific culture.

P16 is a battery of 23 items of school knowledge—at the compulsory levels. The resulting variable of the sum, *Knowledge 23*, has an expectable correlation with battery P14 (Pearson, $r=0.438$; p-value 0.000). Finally, the reason we have only used P16 was that, in spite of it measuring the same as P14, we believe that it better captures that school dimension that we expect in scientific culture of students in initial teacher training; the contrast questionnaire contains no equivalent question to P16, but it does to P14.

2.2.3 Interest in Serious Matters, Interest in Worldly Matters, Interest in Frivolous Matters

We also use questions P1 and P2 (FECYT, 2017) that measure spontaneous interest in different issues and how well informed the subject feels about them. Theory suggests that the interest toward an issue is related with a higher information on the issue and often a positive attitude (Wynne, 1995). P1 and P2 have also been summarised by factorial analysis.

The battery (P1) has three components.

- The factor *Interest in Serious Matters* brings together interest in the *environment and ecology* (loading 0.773); *education* (0.705); *cinema, art, and culture* (0.702); *medicine and health* (0.590); *science and technology* (0.578); *food and consumption* (0.570); and, perhaps, *politics* (0.433). This explains 31.47% of the variance.
- The factor *Interest in Worldly Matters* groups *economics and business* (loading 0.779) and *sports* (0.630) and explains an 11.92% of the variance.
- The factor *Interest in Frivolous Matters* groups the interest in *celebrity matters* (0.767) and *paranormal phenomena and the occult* (0.629) and explains 9.86% of the variance.

2.2.4 Information on Serious Matters, Information on Worldly Matters, Information on Frivolous Matters

The battery (P2) produces groups that we have called in a similar manner in spite of not containing exactly the same items.

- *Information on Serious Matters* includes *medicine and health* (loading 0.736), *environment and ecology* (0.732), *food and consumption* (0.656), and *science and technology* (0.641).
- *Information on Worldly Matters* groups *sports* (0.698) and *economics and business* (0.687).
- *Information on Frivolous Matters* aggregates *paranormal phenomena and the occult* (0.626); *cinema, art, and culture* (0.624); *celebrity matters* (0.565); and *education* (0.521). We have kept the nomenclature in spite our not believing that education is a frivolous matter. It is notable that, among our students, those who claim they are best informed in educational terms also say the same about such frivolous matters.

We have summarised other opinion variables in the survey with the same process of extracting main components (P8, P10, P11, FECYT, 2017), but all of them have been excluded by the procedure.

2.2.5 Caution, Suspicion, Security

Lastly, the battery of items in P12 deals with the social consequences of science and technology. In spite of their heterogeneity, it produces three clear components that appear to group together sentences related to cautious use of science and technology (*Caution*), to suspicion with regard to their use (*Suspicion*), and to full certainty and confidence in that relationship (*Security*). Two items do not have a clear relation to any of the factors. *Caution* explains 28.2% of the variance, *Suspicion* 14%, and *Security* 10.5%. The factors group the respondents into similar types to those described in the literature; generally, the first corresponds to conditional confidence, and it is usually related to the educated public that provides moderate support to science and technology in general; the second, that does intervene in our definitive models, brings together a public that does not trust and is scarcely interested in science; and the third generally corresponds to an acritical confidence, along with scarce culture and little scientific knowledge (Escobar et al., 2015; Quintanilla and Escobar, 2005; Quintanilla et al., 2011; Quintanilla et al., 2019; Santos-Requejo, et al., 2017).

2.2.6 Variables Transformed into Dummies

D9 annotates the family revenue—a proxy of social class—and this was transformed into four dummy variables of which the first was the reference category. The analysis excluded this both from our survey (PCYTMF) as well as in EPSCYT (FECYT, 2017), and these do not appear in the definitive models. D8 annotates religious practice; it has been transformed into a dummy variable that groups non-religious attitudes together (atheism, agnosticism, or indifference, value = 1) with regard to religious attitudes. D7 distinguishes the previous studies and transforms these into three variables (*secondary*

Table 2 Sum of "some", "quite", and "much" in different surveys and cohorts

Valid percentages	PCYTMF		EPSCYT 2016	
	All	Without sec	All	18–23 years
I believe in paranormal phenomena	40.1	45.4	22.7	28.3
Acupuncture works	53.8	55.6	68.5	65.3
What horoscopes predict happens	24.7	29.0	14.9	19.6
Homoeopathic products are effective	40.9	46.3	59.0	57.7
I trust healers	21.6	24.8	23.0	24.3
There are lucky numbers and things	39.5	44.7	28.0	31.7

or vocational training, university studies incomplete, and complete university studies (diploma, degree, or equivalent)). D10 annotates the labour status, and we have transformed it into four dummies. As with the socio-economic ones, these variables do not appear in the definitive models. Lastly, we have simplified the variable D1 "sex" so the points work in the same way (female = 1), and we have called it "Gender".

3 Results

3.1 Descriptive Study, Comparison with the General Population

As we see in Table 1, education students believe more in acupuncture, homoeopathy, paranormal phenomena, and lucky numbers than in horoscopes and healers. To us, this is surprisingly high proportions of believers, given that they are students with slightly higher level of studies than their age group.

Respondents' beliefs are like those of the overall population and of the 15–24 years population (see Rogero-García & Lobera, 2017, p. 216). Our students believe more in every superstition but believe less in *acupuncture* and *homoeopathy*.

Table 2 compares more precisely the proportion of believers within the same age group in the public. The pattern remains the same with the sum of answers "some", "quite", and "much" in each variable (first column). The second column only include preschool and primary teachers in training, and the third and fourth columns compare them (PCYTMF) with the results in EPSCYT 2016—the overall population and its 18–23 year-old cohort.

Education students believe more than the general population in most of the superstitions and slightly less in pseudoscience (acupuncture and homoeopathy)—although they believe the most in these, as the public does. Compare the second column, mostly made of students between 18 and 23 years, with the fourth one: teachers in training seem to believe more than the population of their cohort, against our hypotheses—that says that their slightly higher education and their class *immunise* them to some extent. But the comparison of the first two columns shows that the small proportion of secondary school teachers in training tends to moderate that strong tendency in our sample: younger students do believe more in every creed. It can be an effect of age or of the education level.

Table 3 OLS regression models using PCYTMF survey

		1	2	3	4
(Constant)		1.323	0.564	1.039	0.193
	Sig.	*0.000*	*0.003*	*0.000*	*0.001*
(P16) Knowledge 23		−0.042			
	Sig.	*0.003*			
(D2) Age		−0.021		−0.034	
	Sig.	*0.043*		*0.009*	
(D8) Religion, non-believer, or indifferent		−0.337	−0.230	−0.378	−0.236
	Sig.	*0.000*	*0.002*	*0.000*	*0.006*
(D7) Complete university (Grade equiv., at least)		−0.562	−0.416		
	Sig.	*0.000*	*0.000*		
(P1) Interest in serious matters			−0.139		−0.181
	Sig.		*0.001*		*0.001*
(P1) Interest in frivolous matters			0.426		0.445
	Sig.		*0.000*		*0.000*
(P2) Information on serious matters			0.160		0.182
	Sig.		*0.001*		*0.001*
(P12) Suspicion, according to the sentences suggested			0.097		0.111
	Sig.		*0.008*		*0.010*
ANOVA	*F*	32.30	35.58	14.07	22.79
	Sig.	*0.000*	*0.000*	*0.000*	*0.000*
	R^2	19.4%	32.3%	5.7%	20.4%
	n	543	530	472	450

Dependent: "Identification with different beliefs".

3.2 Explanatory Study, Socio-economic Factors that Influence These Beliefs

What factors influence those beliefs? The pre-service teacher group is more restricted and provides less variation than the general population in known factors that have been found explanatory, such as age, level of studies, and income. Specifically, we have applied the OLS analysis method with the variables stated above in the section on Methodology. In Table 3, we present the definitive models: we remove the variables that do not have any effect, or those that may display multicollinearity, and we repeat the operation until obtaining a model of each one. We do not use the SPSS stepwise procedure or any similar one. Model 1, with the socio-demographic variables and some elementary opinion ones, includes all the valid replies in the data base and retains 543 respondents (including the secondary Master students). Model 2 shows the result of the analysis when including opinion variables on the science of the same survey, such as "interest" or "information" in different matters. The following two models are those obtained from analysis of the same variables, but they exclude the 90 secondary Master students, who are very different to the rest of the sample in studies and age.

In model 1, four variables explain a 19.4% of the total variance: the higher the age is, the lower the identification with superstitious or pseudoscientific beliefs; likewise, the higher the scientific culture—measured with "Knowledge 23"—the lower that identification;

non-believers or those indifferent to religion tend to reject those beliefs; lastly, those who have a qualification in tertiary education tend to hold such beliefs less than those who do not. As may be seen, the influence of age is relatively independent from that of having tertiary education (as both variables are included in the model), in spite of the secondary Master students also being older.

When the opinion variables are included (model 2), age and scientific knowledge cease to be significant. The opinion and attitude variables are more explanatory. Having university studies and being indifferent to religion or a non-believer continue to limit pseudoscientific and superstitious beliefs, as we could expect. People who have shown an *Interest in serious matters*, that include interest in science and technology, tend to reject superstitious beliefs. Obviously, *Interest in frivolous matters* will favour identification with superstitious and pseudoscientific beliefs: its *beta value* (not shown) is the highest of all the variables of the model and is the one that has the most influence. It is strange that people who say they are *informed regarding serious matters* (P2 variable) appear to be nearer to such beliefs; it is also a paradox because if we compare it with the effect of spontaneous *interest in serious matters* (P1 variable), it is just the opposite. It contradicts our expectations, and we do not have an explanation for this. The variable *Suspicion* also intervenes in model 2, in which factor analysis groups together the items "Science and technology are a source of risk to our society" (loading 0.716) and "We cannot trust scientists to tell the truth if they depend on private financing" (0.635). Those who agree with these sentences tend to identify with superstitious beliefs. This model 2 explains a 32.3% of variance.

Small model 3 confirms that age prevents superstition in spite of the sample having been reduced to 472 students from a narrow age cohort. Their standardised coefficient (not shown here) is the largest of the model. Those who declare they have no religious belief also tend not to identify with superstitious or pseudoscientific beliefs. As may be seen, the model excludes the variables that represent the level of studies. The fact of the model having just two variables may be due to the smaller sample, like the small R^2, that is 5.7%.

In model 4, that explains the 20.4% variance, we study the opinion variables again: this model excludes the variable representing scientific culture (*Knowledge 23*) and that of studies, but also that of age: this is understandable, as we have excluded the secondary master students, which reduces the variability. The rest of the variables included behave according to a similar pattern to that of model 2.

In Table 4, we compare with the age group from 18 to 23 years among the general population (in the survey EPSCYT; FECYT, 2017, 2019). We present the ordinary least squares regression analysis with the three dependent variables that measure nearness to superstitions or pseudoscience (see Table 4):

- *Superstition*, in model 5, based on the first component of the factorial analysis in question 26 of EPSCYT 2016, that merges various items from it: "what horoscopes predict happens", "there are lucky numbers and things", "I believe in paranormal phenomena", and "I trust healers" (Santos Requejo et al., 2017, p. 291).
- *Pseudoscience*, model 6 merges the replies to the items "acupuncture works" and "homoeopathic products are effective".
- *Beliefs* (model 7) is a simple average of all the items in P26.

The table presents the definitive models, after excluding the independent variables that do not have effect. In the three models, we select youths between 18 and 23 years, the approximate age of pre-service teachers.

Table 4 OLS regression models using EPSCYT survey

	5	6	7
(Constant)	1.311	−0.075	2.821
Sig	*0.000*	*0.662*	*0.000*
Gender, female		0.258	0.227
Sig		*0.001*	*0.001*
Education, secondary		0.272	0.187
Sig		*0.001*	*0.007*
Oxford, sum of the questionnaire	−0.189	−0.072	−0.144
Sig	*0.000*	*0.038*	*0.000*
Agnostic, atheist, indifferent	−0.264		−0.194
Sig	*0.004*		*0.006*
Habitat, rural	−0.202		−0.186
Sig	*0.037*		*0.013*
ANOVA *F*	15.104	8.061	12.459
Sig	*0.000*	*0.000*	*0.000*
R^2	7.8%	3.9%	10.3%
N	502	524	502

Dependent variables: (5) *Superstition*, (6) *Pseudoscience*, and (7) *Beliefs* (sum of both).

As we may see, those with lower marks in scientific culture (sum of the Oxford questionnaire) identify more with superstition, those who say they are religious or believers, and those who live in an urban setting—cities with more than 10,000 inhabitants (model 5). Those who identify more with pseudoscience (model 6) are women, those who have secondary or baccalaureate studies (not higher or lower), and those who have less culture; this model explains little of total variance, less than 4%, and only the ANOVA result suggests that we may trust it. The last model (7) shows that those who identify with such pseudoscientific beliefs and superstitions are women, those who have a secondary education level, those who have less scientific culture, those who are not atheists or indifferent to religious matters, and those who do not live in a rural setting. These variables clearly explain somewhat more than 10% of the variance.

4 Conclusions

As we have seen, our main hypothesis does not hold pre-service teachers hold about the same pseudoscientific and superstitious beliefs that other members of their age cohort in spite of being slightly different in the main explanatory variables—education and family income. With regard to the first objective, to identify beliefs in pseudoscience and superstitions, we have found that Spanish pre-service teachers in the sample are not different of their age group. They usually believe more in some superstitions and slightly less in some pseudosciences like acupuncture and homoeopathy.

The second objective consisted of analysing the factors that influence such beliefs. In our sample, we have confirmed that the attitudes toward pseudoscience and superstition depends on the scientific culture, as indicated in recent literature on PUS: the influence is small but robust. That slight influence is independent of the level of studies the person has, although we have not been able to check whether it depends on the type of studies. In all cases, although the scarce number with high level studies in our sample limits our conclusions, we have found an independent influence of the level of studies to limit believing in pseudoscience and superstitions. Although our sample is narrower in education and family income, due to average pre-service teachers' origins, the explanations for their attitudes toward pseudoscience and superstitions are alike.

Also, in keeping with what the literature suggests, there is an influence of age and religious attitudes. In the first case, this is in the sense that such beliefs decrease the older one is, despite our sample being narrow in the age range. In the second case, non-believers tend not to believe in superstitions and pseudoscience, as if their scepticism extends to other beliefs. However, on the contrary to what the literature suggests, gender has no influence, according to our data—although women are strongly overrepresented—nor does social class. The latter may perhaps be due to the social origin of the pre-service teachers, who to a larger extent come from a narrow, very homogeneous stratus of the intermediate-income classes.

There are not many differences. Pre-service teachers seem to be positively influenced by spontaneous interest in science and other *serious matters*, contrary to their counterparts; and they seem to be negatively influenced by spontaneous interest in superstitions and pseudoscience and other *frivolous matters*, correspondingly. *Gender* influences the belief in pseudosciences in the general population but that's not shown among pre-service teachers, that over-represent women. And, finally, an attitude of suspicion toward science favours non-scientific believes among pre-service teachers.

Although the level of studies tends to moderate such beliefs, as in the case of secondary master students who already have previous qualifications, acceptance or rejection appears to depend on a type of personality, perhaps socialisation in a different social environment. The literature, as we have seen, suggests that this may be the case, as it also suggests that it may depend on the income level—although here we have not been able to ascertain this due to the scarce variation in the sample in that sense. The normative expectation would be for future teachers to trust less in superstitious and pseudoscientific beliefs. However, if that attitude were prior, it would be difficult for their scientific enlightenment and studies to limit such beliefs: that would be the result of ampler social dynamics, such as the ways in which one ends up belonging to a social group.

These results have implications in training scientific teachers and in the scientific literacy of the population. We consider it is necessary for scientific teaching to approach the daily environment more. To include elements of the students' social context, moreover, school science should contribute to teach that superstitions, and pseudoscience is not reliable knowledge. To that end, future educational professionals must include these results in their training, as regarding how science works in social contexts. In any case, one must bear in mind that such non-scientific beliefs are persistent and difficult to eradicate. Thus, as happened with *alternative conceptions*, these beliefs must be considered when designing classroom proposals and be used as a resource to ensure that future generations have a better comprehension of the true nature of science.

Annex 1

The questionnaire PCYTMF survey is a replica of the EPSCYT 2016 one (FECYT, 2017), see https://www.fecyt.es/sites/default/files/users/user378/cuestionario_epscyt_2016_vf_0.pdf at https://www.fecyt.es/es/noticia/encuestas-de-percepcion-social-de-la-cienc ia-y-la-tecnologia-en-espana. There are a few changes, however. Identification questions are suited to our population and some of the demographic ones. The wording is slightly informal. It contains 33 questions that sum a total of 170 items. There are three main changes in the questions:

- Question P14 is an *Oxford questionnaire*, a battery of general science questions, some of them deliberately controversial. Ours sum questions of both the EPSCYT 2016 and the EPSCYT 2018, eight items.
- Question P16 is another questionnaire of science items aimed for college students: these are common questions in the sciences curriculum that they should know. It was written after consultation and debate within the team (Fernández Carro et al., 2021). It has 23 items.
- Finally, question P11 is adapted from the questionnaire made by *Ipsos Reid Public Affairs* in 2006 for the Government of Alberta, Canada, items 1, 2, 3, 4, 6, and 7, taken from Roduta Roberts et al., (2013, p. 631). It is a common question in science attitudes surveys. It was finally rejected by the regression models.

P.14. You must now choose between the paired statements: please tell us which one is correct. Reply from what you know, and do not ask your companions (this is not an exam). In this case, there are correct answers, but this is not an exam.

Antibiotics cure infections caused by both viruses and bacteria	Antibiotics cure infections caused by bacteria
* Continents have always been and will always be in movement	Continents always remain in the same place
* Laser rays operate by concentrating sound waves	Laser rays operate by concentrating waves of light
The first human beings lived at the same time as the dinosaurs	Human beings have never lived with dinosaurs
When a person eats genetically modified fruit, their genes may also be modified	Eating genetically modified fruit does not affect the genes of the person eating it
** Present climate change is a consequence of the hole in the ozone layer	Present climate change is mainly due to accumulation of greenhouse gases
** The number pi (π) is usually applied, among other things, in manufacturing tyres	The number pi (π) is the relation between the legs and hypotenuse of a triangle
The sun rotates around the earth	The earth rotates around the sun

The single asterisk (*) signals questions in EPSCYT 2016 that were substituted by those with the double asterisk (**) in EPSCYT 2018. We test this eight-item version, but finally preferred P16 in models 1 to 4 (Table 3).

P.16. And to conclude this part, we ask you to choose again between paired statements. Remember that it is not an exam, and reply from what you know. Again, there are correct answers here, but we are not evaluating you for the course.

There may be movement without applied force	If there is no force, there is no movement
Oxidation is inherent only to metals	Apart from metals, oxidation takes place in other substances
Heat cannot be stored	Bodies store heat
When a body dilates, it weighs more	A dilated body weighs the same as prior to dilating
Whenever heat is applied, the temperature rises	Heat may be applied without the temperature changing

Electric current remains constant during the whole time it runs round a circuit	Electric current is used up when it runs through the elements of a circuit
Only some metals are attracted by magnets	Magnets attract all metals
Air only exerts pressure when it moves	Air always exerts pressure, even though it does not move
Bodies store force	Force cannot be stored
Plants produce oxygen, but they do not consume it	Plants produce and consume oxygen
The greenhouse effect is always harmful for life on earth	The greenhouse effect is necessary for life on earth
Rocks are formed and destroyed continually	Rocks are not substantially altered from their formation
Magma comes from the layers nearest to the surface of the earth	Magma comes from earth's core
Seasons are due to the nearness or distance between the sun and the earth	Seasons are due to the angle at which sun's rays strike the earth
The number of chromosomes in daughter cells after a process of mitosis is the same as that of the parent cell	The number of chromosomes in daughter cells after a process of mitosis is the same as that of the parent cell
Corals are marine animals	Corals are marine plants
Sexual reproduction takes place in plants and animals	Sexual reproduction only takes place in animals
Chemical processes are always of an artificial type	Chemical processes may be artificial or natural
Plants and animals adapt and modify the ecosystem they live in	Plants and animals adapt to the environment they live in
In chemical reactions, some atoms disappear and transform themselves into others	In chemical reactions, atoms do not disappear, they only reorganise themselves
The mass of an atom is concentrated in a very small core	The mass of an atom is distributed uniformly
The majority of the water on the planet earth is fresh water	The majority of the water on the planet earth is salt water
When sugar is dissolved in water, we obtain a new substance	When water is dissolved in water, we still have sugar and water
Fossils are petrified remains of animals from the past	Fossils are remains from biological activity in the past
Viruses are not destroyed by antibiotics	Viruses are combated using antibiotics
There can be no more matter between two elementary particles of matter	There is more matter between two elementary particles of matter

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Declarations

Conflict of Interest The authors declare that they have no conflict of interest.

References

Albe, V. (2008). Students' positions and considerations of scientific evidence about a controversial socioscientific issue. *Science & Education, 17*(8), 805–827. https://doi.org/10.1007/s11191-007-9086-6

Astin, J. A. (1998). Why patients use alternative medicine. *Journal of the American Medical Association, 279*(19), 1548–1553. https://doi.org/10.1001/jama.279.19.1548

Astin, J. A. (2000). The characteristics of CAM users: A complex picture. In M. Kelner & B. Wellman (comps.), *Complementary and alternative medicine: Challenge and change* (pp. 101–114). Harwood Academic Publishers.

Bak, H.-J. (2001). Education and public attitudes toward science: Implications for the "deficit model" of education and support for science and technology. *Social Science Quarterly, 82*(4), 779–795. https://doi.org/10.1111/0038-4941.00059

Ballová Mikušková, E. (2018). Conspiracy beliefs of future teachers. *Current Psychology, 37*, 692–701. https://doi.org/10.1007/s12144-017-9561-4

Boudry, M., Paglieri, F., & Pigliucci, M. (2015). The fake, the flimsy, and the fallacious: Demarcating arguments in real life. *Argumentation, 29*, 431–456. https://doi.org/10.1007/s10503-015-9359-1

Bybee, R. W. (1991). Science-technology-society in science curriculum: The policy-practice gap. *Theory into Practice, XXX*(4), 294–302. https://doi.org/10.1080/00405849109543515

Bybee, R. W. (1997). Towards an understanding of scientific literacy. In W. Gräber & C. Bolte (Eds.), *Scientific literacy. An international symposium* (pp. 37–68). Institut für die Pädagogik der Naturwissenschaften (IPN).

Cano-Orón, L., Mendoza-Poudereux, I., & Moreno-Castro, C. (2019). Perfil sociodemográfico del usuario de la homeopatía en España. *Atención Primaria, 52*(8), 499–505. https://doi.org/10.1016/j.aprim.2018.07.006

Çekbaş, Y., & Çokadar, H. (2015). The effect of argumentation-oriented astronomy teaching on preservice teachers' pseudoscientific beliefs. *TOJET. The Turkish Online Journal of Educational Technology*, (Special Issue for INTE 2015, August*)*, 581–585.

Cortassa, C. (2016). In science communication, why does the idea of a public deficit always return? The eternal recurrence of the public deficit. *Public Understanding of Science, 25*(4), 447–459. https://doi.org/10.1177/0963662516629745

Confederación de Sociedades Científicas de España, COSCE. (2011). *Informe Enciende. Enseñanza de las Ciencias en la Didáctica Escolar para edades tempranas de España*. COSCE.

DeBoer, G. (2000). Scientific literacy: Another look at its historical and contemporary meanings and its relationship to science education reform. *Journal of Research in Science Teaching, 37*(6), 582–601.

Doygun, Y., Ozcan, H., & Tasar, F. (2019). An investigation of pre-service science teachers' understanding of the concepts 'science' and 'pseudoscience.' In F. Seroglou & V. Koulountzos (Eds.), *Re-introducing science. Sculpting the image of science for education and media in its historical and philosophical background* (pp. 445–451). International History Philosophy and Science Teaching Group, IHPST.

Eisenberg, D. M., Davis, R. B., Ettner, S. L., Appel, S., Wilkey, S., Van Rompay, M., & Kessler, R. C. (1998). Trends in alternative medicine use in the United States, 1990–1997: Results of a follow-up national survey. *Journal of the American Medical Association, 280*(18), 1569–1575. https://doi.org/10.1001/jama.280.18.1569

Escobar, M., Quintanilla, M. Á., & Santos-Requejo, L. (2015). Indicadores de cultura científica por Comunidades Autónomas. In FECYT (Ed.), *Percepción Social de la Ciencia y la Tecnología en España 2014*, (pp. 189–215). Fundación Española para la Ciencia y la Tecnología, FECYT.
European Commission, EC. (2005). *Special Eurobarometer 224: Europeans, science and technology*. European Commission.
European Commission, EC, High Level Group on Science Education. (2007). *Science education now: A renewed pedagogy for the future of Europe*. European Commission.
European Commission, EC. (2013). *Special Eurobarometer 401: Responsibly Research and Innovation (RRI), Science & Technology*. European Commission.
Eve, R. A., & Dunn, D. (1990). Psychic power, astrology and creationism in the classroom? Evidence of pseudoscientific beliefs among high school biology & life science teachers. *The American Biology Teacher, 52*(1), 10–21. https://doi.org/10.2307/4449018
Ezquerra, A., Fernández-Sánchez, B., Magaña, M., & Mingo, B. (2017). Analysis of scientific contents of household cleaning products' labelling and its language implications. *Journal of Turkish Science Education*, *14*(1) 73–88. https://doi.org/10.12973/tused.10191a. ISSN: 1304-6020.
Feinstein, N. (2011). Salvaging science literacy. *Science Education, 95*(1), 168–185.
Feinstein, N. W., Allen, S., & Jenkins, E. (2013). Outside the pipeline: Reimagining science education for nonscientists. *Science, 340*(6130), 314–317. https://doi.org/10.1126/science.1230855
Fernández-Carro, R, Benéitez, A. E., Vílchez, J. E., Ceballos, M., Reina, M., & Ezquerra, A. (2021). Alfabetización científica de los estudiantes de Educación en España. EDGE29, Nuevos horizontes en la enseñanza y aprendizaje de las Ciencias. Córdoba, February 10–12, 2021
Fjær, E. L., Landet, E. R., McNamara, C. L., & Eikemo, T. A. (2020). The use of complementary and alternative medicine (CAM) in Europe. *BMC Complementary Medicine and Therapies, 20*, 1–9. https://doi.org/10.1186/s12906-020-02903-w
Fuertes-Prieto, M. Á., Andrés-Sánchez, S., Corrochano-Fernández, D., Urones-Jambrina, C., Delgado-Martín, M. L., Herrero-Teijón, P., & Ruiz, C. (2020). Pre-service teachers' false beliefs in superstitions and pseudosciences in relation to science and technology. *Science & Education, 29*(5), 1235–1254. https://doi.org/10.1007/s11191-020-00140-8
Fundación Española para la Ciencia y la Tecnología, FECYT. (2017). *Percepción Social de la Ciencia y la Tecnología, 2016*. Ministerio de Economía, Industria y Competitividad. Fundación Española para la Ciencia y la Tecnología.
Fundación Española para la Ciencia y la Tecnología, FECYT. (2019). *Percepción Social de la Ciencia y la Tecnología, 2018*. Ministerio de Ciencia e Innovación. Fundación Española para la Ciencia y la Tecnología, FECYT.
García-Carmona, A., & Acevedo Díaz, J. A. (2016). Learning about the nature of science using newspaper articles with scientific content. *Science & Education, 25*(5), 523–546. https://doi.org/10.1007/s11191-016-9831-9
Genovese, J. E. C. (2005). Paranormal beliefs, schizotypy, and thinking styles among teachers and future teachers. *Personality and Individual Differences, 39*(1), 93–102. https://doi.org/10.1016/j.paid.2004.12.008
Hodson, D. (2003). Time for action: Science education for an alternative future. *International Journal of Science Education, 25*(6), 645–670. https://doi.org/10.1080/09500690305021
Hodson, D. (2011). *Looking to the future*. Springer Science & Business Media.
Kaplan, A. O. (2014). Research on the pseudoscientific beliefs of preservice science teachers: A sample from astronomy-astrology. *Journal of Baltic Science Education, 13*(3), 381–393.
Kemppainen, L. M., Kemppainen, T. T., Reippainen, J. A., Salmenniemi, S. T., & Vuolanto, P. H. (2018). Use of complementary and alternative medicine in Europe: Health-related and sociodemographic determinants. *Scandinavian Journal of Public Health, 46*(4), 448–455. https://doi.org/10.1177/1403494817733869
Kolstø, S. D. (2006). Patterns in students' argumentation confronted with a risk-focused socio-scientific issue. *International Journal of Science Education, 28*(14), 1689–1716. https://doi.org/10.1080/09500690600560878
Lederman, N. G. (1999). Teachers' understanding of the nature of science: Factors that facilitate or impede the relationship. *Journal of Research in Science Teaching, 36*(8), 916–929. https://doi.org/10.1002/(SICI)1098-2736(199910)36:8%3C916::AID-TEA2%3E3.0.CO;2-A
Lewis, J., & Leach, J. (2006). Discussion of socio-scientific issues: The role of science knowledge. *International Journal of Science Education, 28*(11), 1267–1287. https://doi.org/10.1080/09500690500439348

Levinson, R. (2006). Towards a theoretical framework for teaching controversial socio-scientific issues. *International Journal of Science Education, 28*(10), 1201–1224. https://doi.org/10.1080/09500690600560753

Losh, S. C., & Nzekwe, B. (2011). The influence of education major: How diverse preservice teachers view pseudoscience topics. *Journal of Science Education and Technology, 20*(5), 579–591. https://doi.org/10.1007/s10956-011-9297-0

Michael, M. (1992). Lay discourses of science: Science-in-general, science-in-particular, and self. *Science, Technology, & Human Values, 17*(3), 313–333. https://doi.org/10.1177/016224399201700303

OECD. (2019a). *PISA 2018 Results (Volume I): What students know and can do*. OECD Publishing. https://doi.org/10.1787/5f07c754-en

OECD. (2019b). *PISA 2018 Results (Volume II): Where all students can succeed*. OECD Publishing. https://doi.org/10.1787/b5fd1b8f-en

Pigliucci, M., & Boudry, M. (Eds.). (2013). *Philosophy of pseudoscience: Reconsidering the demarcation problem*. University of Chicago Press. https://doi.org/10.7208/chicago/9780226051826.001.0001

Preece, P. F. W., & Baxter, J. H. (2000). Scepticism and gullibility: The superstitious and pseudo-scientific beliefs of secondary school students. *International Journal of Science Education, 22*(11), 1147–1156. https://doi.org/10.1080/095006900501667244

Quintanilla, M. Á., & Escobar, M. (2005). Un indicador de cultura científica para las comunidades autónomas. In FECYT (Ed.), *Percepción Social de la Ciencia y la Tecnología en España 2004*, 223–232. Fundación Española para la Ciencia y la Tecnología, FECYT.

Quintanilla, M. Á., Escobar, M., & Quiroz, K. (2011). La actitud global hacia la ciencia en las comunidades autónomas. In FECYT (Ed.), *Percepción Social de la Ciencia y la Tecnología en España 2010*: 137–157. Fundación Española para la Ciencia y la Tecnología, FECYT.

Quintanilla, M. Á., Escobar, M., & Santos, L. (2019). Perfiles de cultura científica ciudadana. Sus características y su relación con prácticas no científicas. In FECYT (ed.) *Percepción social de la ciencia y la tecnología, 2018*, 84–105. Fundación Española para la Ciencia y la Tecnología, FECYT.

Rayner, L., & Easthope, G. (2001). Postmodern consumption and alternative medications. *Journal of Sociology, 37*(2), 157–176. https://doi.org/10.1177/144078301128756274

Roduta Roberts, M., Reid, G., Schroeder, M., & Norris, S. P. (2013). Causal or spurious? The relationship of knowledge and attitudes to trust in science and technology. *Public Understanding of Science, 22*(5), 624–641.

Rogero-García, J., & Lobera, J. (2017). Márgenes difusos: La confianza en las pseudociencias. In J. Lobera (Ed.), *Percepción social de la ciencia y la tecnología, 2016* (pp. 208–224). Ministerio de Economía, Industria y Competitividad, Fundación Española para la Ciencia y la Tecnología.

Rozbroj, T., Lyons, A., & Lucke, J. (2019). Psychosocial and demographic characteristics relating to vaccine attitudes in Australia. *Patient Education and Counseling, 102*(1), 172–179. https://doi.org/10.1016/j.pec.2018.08.027

Santos-Requejo, L., Escobar Mercado, M., & Quintanilla Fisac, M. Á. (2017). Dimensiones y modelos de cultura científica: Implicaciones prácticas para la financiación y la demarcación de la ciencia. In J. Lobera Serrano (Ed.), *Percepción social de la ciencia y la tecnología, 2016* (pp. 277–305). Ministerio de Economía, Industria y Competitividad, Fundación Española para la Ciencia y la Tecnología.

Schmaltz, R., & Lilienfeld, S. O. (2014). Hauntings, homeopathy, and the Hopkinsville Goblins: Using pseudoscience to teach scientific thinking. *Frontiers in Psychology, 5*, 336. https://doi.org/10.3389/fpsyg.2014.00336

Shen, B. S. P. (1975). Science literacy: Public understanding of science is becoming vitally needed in developing and industrialized countries alike. *American Scientist, 63*(3), 265–268. https://www.jstor.org/stable/27845461.

Solbes Matarredonda, J., Palomar Fons, R., & Domínguez Sales, M. C. (2018). To what extent do pseudosciences affect teachers? A look at the mindset of science teachers in training. *Mètode Science Studies Journal, 8*, 188–195. https://doi.org/10.7203/metode.8.9943

Southerland, S. A., Golden, B., & Enderle, P. (2012). The bounded nature of science: An effective tool in an equitable approach to the teaching of science. In M. Khine (Ed.), *Advances in Nature of Science Research* (pp. 75–96). Springer. https://doi.org/10.1007/978-94-007-2457-0_4

Thomas, K. J., Nicholl, J. P., & Coleman, P. (2001). Use and expenditure on complementary medicine in England: A population based survey. *Complementary Therapies in Medicine, 9*(1), 2–11. https://doi.org/10.1054/ctim.2000.0407

Tseng, Y.-C., Tsai, C.-Y., Hsieh, P.-Y., Hung, J.-F., & Huang, T.-C. (2014). The relationship between exposure to pseudoscientific television programmes and pseudoscientific beliefs among Taiwanese university students. *International Journal of Science Education, Part B: Communication and Public Engagement, 4*(2), 107–122. https://doi.org/10.1080/21548455.2012.761366

United Nations Educational, Scientific and Cultural Organization, UNESCO. (1999). *Declaration on science and the use of scientific knowledge*. Adopted by the World Conference on Science, 1 July 1999. Budapest, Hungary.
Vázquez-Alonso, Á., García-Carmona, A., Manassero-Mas, M. A., & Bennàssar-Roig, A. (2013). Science teachers' thinking about the nature of science: A new methodological approach to its assessment. *Research in Science Education, 43*(2), 781–808. https://doi.org/10.1007/s11165-012-9291-4
Wynne, B. (1995). Public understanding of science. In S. Jasanoff, G. E. Markle, J. C. Petersen, & T. Pinch (comp.), *The Handbook of Science and Technology* (pp. 361–389). SAGE.
Yearley, S. (1994). Understanding science from the perspective of the sociology of scientific knowledge: An overview. *Public Understanding of Science, 3*, 245–258. https://doi.org/10.1088/0963-6625/3/3/001
Zeidler, D. L., Walker, K. A., Ackett, W. A., & Simmons, M. L. (2002). Tangled up in views: Beliefs in the nature of science and responses to socioscientific dilemmas. *Science Education, 86*(3), 343–367.