Attitudes towards Science and the impact of epistemic beliefs on pre-service primary teachers' scientific literacy

AIKATERINI SARGIOTI, ANASTASSIOS EMVALOTIS

Laboratory of Didactics and School Pedagogy
Department of Primary Education
University of Ioannina
Greece
katsargioti@gmail.com
aemvalot@uoi.gr

ABSTRACT
Attitudes towards science have an important role in society, as they affect people's scientific literacy, which is cultivated from an early age, leading to the need for scientific literate teachers. The purpose of the present study was to detect pre-service teachers' attitudes towards science and examine whether their beliefs about science influence their scientific literacy or not. One hundred and eighty-six Primary Education students from Greece participated in the study. The participants completed an online questionnaire about themselves and their family as well as their views and their attitudes towards science. The questionnaire used in the Programme for International Student Assessment (PISA) was adapted to the requirements of this study, in order to reveal individuals' attitudes. The results confirmed that scientific literacy is composed of five indices, some of which are affected by gender, high school courses and year of studies. Moreover, the research data show a significant relationship between participants' science performance and their beliefs about science.

KEYWORDS
Scientific literacy, attitudes towards science, epistemic beliefs, PISA

RÉSUMÉ
Les attitudes envers la science jouent un rôle décisif dans la société du fait qu'elles influencent la littératie scientifique des citoyens, laquelle est cultivée dès leur jeune âge, ce qui augmente le besoin d'enseignants en mesure de posséder des connaissances et des compétences en science. Le but de la présente étude était d'étudier les points de vue des étudiants de l'éducation préscolaire et de l'éducation primaire sur la science et d'examiner si leurs croyances au sujet de la science influencent leur littératie scientifique. 180 étudiants grecs de l'éducation primaire ont participé à la présente recherche. Les participants ont rempli un questionnaire électronique recueillant des informations sur eux-mêmes et leurs familles, ainsi que des informations sur leurs points de vue et attitudes à l'égard de la science. Le questionnaire utilisé dans le cadre de la recherche PISA (Programme for International Student Assessment) a été adapté aux exigences de la présente recherche pour refléter les attitudes des individus. Les résultats ont confirmé que la culture scientifique se compose de cinq indicateurs, dont certains sont influencés par le sexe des participants, les cours qu'ils ont suivis au lycée et l'année d'études. Les résultats ont confirmé que la culture scientifique se compose de cinq indicateurs, dont certains sont influencés par le sexe des participants, les cours qu'ils ont suivis au lycée et l'année d'études. De plus, les données de recherche montrent une relation significative entre la performance des participants dans les sciences naturelles et leurs croyances sur la science.

MOTS-CLÉS
Littératie scientifique, attitudes envers la science, croyances scientifiques, PISA

INTRODUCTION

Nowadays, education aims at nourishing people, willing and able to participate in social life and implement their knowledge in any situation of their everyday life, either familiar or non-familiar (Li & Frieze, 2016; Sadler & Zeidler, 2009). As a result, scientific literacy, individuals' ability to solve everyday problems, is the most important goal of science education (Millar, 2006; Roberts, 2007).

One of the most well-known surveys that assesses students' scientific literacy, at an international level, is PISA conducted by the Organisation for Economic Co-operation and Development (OECD). With reference to the adult population, a similar survey that evaluates, also at an international level, people's readiness to use their knowledge so as to participate in real situations of everyday life is The Programme for the International Assessment of Adult Competencies (PIAAC), also conducted by OECD.

A basic feature of the development of scientific literacy is scientific knowledge (Bybee & McCrae, 2011; Lau & Lam, 2017; OECD, 2016a; Roberts, 2007). As scientific knowledge starts to grow from an early age, it is necessary scientific literacy be developed from the very early years of compulsory education. Therefore, it becomes significant for primary school teachers to have knowledge and skills that will enable them to actively participate in their students' skills formation, skills that have a key role in scientific literacy.

The present study examines how scientific literate are primary education students and the impact of epistemic beliefs on their science literacy.

THEORETICAL BACKGROUND

Science and scientific knowledge

Science is a procedure that tries to explain to explain the world (Chalmers, 2013; Lofaso, 2006). It can be described through three different, but complementary, approaches (Lederman, 2007). More specifically, it is described as 'body of knowledge', including a range of concepts, theories and ideas in order to be constructed (Lederman, 2007; Lofaso, 2006). Supplementary to the above description, science is approached as 'method' of knowledge constitution, something that focuses on scientists' acts trying to construct the body of knowledge (Lederman, 2007; Lederman & Lederman, 2012). Lastly, it is portrayed as a 'way of knowing', that is knowledge which is based on scientists' usage of procedures, methods and strategies, while trying to explain the world (Bybee, 2006; Lederman, 2007; Lederman & Lederman, 2012).

Science as way of knowing refers to 'nature of science' (Lederman, 2007). Its main goal is new knowledge to be developed, taking into consideration the values and the beliefs with which science is directly linked (Lederman, 2007; Khishfe, 2017; Michel & Neumann, 2016). In order to understand science, it is vital nature of science be comprehended (Leblebicioglu et al., 2017). Scientific knowledge should be cultivated for the purpose of understanding nature of science sufficiently (Archer-Bradshaw, 2017; Lederman & Lederman, 2012). It is described through a set of special features which should also be understood (Lederman, 2007). Firstly, it is defined as 'tentative', which means that it is not absolute and certain, but it can be modified. Secondly, it is presented as 'empirically based', based on observations of the natural world, and simultaneously 'subjective', as it includes independent researchers' approaches and interpretations. Finally, it is based on 'inference', 'imagination' and 'creativity' and, finally, it is 'socially and culturally embedded' (Lederman, 2007). All these features are correlated with each other in their attempt to explain the tentative nature of scientific knowledge (Bell, 2006).

Apart from this classification, scientific knowledge is separated into two other sections, 'knowledge of science' and 'knowledge and understanding about science' (Bybee & McCrae, 2011; OECD, 2006). The first one describes the 'content knowledge', which means the knowledge of the natural world related to everyday life situations and the understanding of different scientific theories (Bybee & McCrae, 2011; OECD, 2006, 2016a). The second one displays a person's possibility to understand the nature of science through scientific inquiry (Lederman & Lederman, 2012; OECD, 2006, 2016a; Schwartz, Lederman & Lederman, 2008). Knowledge and understanding about science represent two individual forms of knowledge, 'procedural knowledge', generally, the understanding of the data collection methods, data analysis and interpretation, and 'epistemic knowledge', which facilitates the person to recognize the characteristics of scientific inquiry and utilize its processes and practices so as to participate in it (Duschl, 2007; Lederman & Lederman, 2012; OECD, 2016a).

Scientific literacy and scientific competencies

One well known international assessment that evaluates 15-year-old students' scientific literacy is PISA. It is conducted by OECD every three years. The survey assesses three fields, reading, mathematics and science, in every cycle. One of the fields is the main focus at each cycle of the assessment. In 2000, 2009 and 2018 the main field was reading, in 2003 and 2012 mathematics, and in 2006 and 2015 science. Since 2003 it has been assessed problem solving, while in 2015 cooperative problem solving as well as global competence were also included in the survey (OECD, 2006, 2016a).

According to OECD (2016a) scientific literacy is defined as: "*the ability to engage with science-related issues, and with the ideas of science, as a reflective citizen. A scientifically literate person is willing to engage in reasoned discourse about science and technology, which requires the competencies to explain phenomena scientifically, evaluate and design scientific enquiry and interpret data and evidence scientifically*" (2016a, p. 13).

Scientific literacy in PISA is assessed through four interrelated aspects (OECD, 2016a). The first aspect is 'contexts'. There are integrated the questions which students should answer, regarding to personal, local and national and global issues. The cognitive issues are related to health, natural resources, environmental quality, hazards and frontiers of science and technology (OECD, 2016a).

Furthermore, it is essential students demonstrate specific 'competencies' to successfully solve problems. First of all, individuals should be able to 'explain phenomena scientifically' (OECD, 2006, 2016a). That means, that they have to use their knowledge in order to interpret everyday phenomena through hypothesis. Afterwards, individuals should develop their competency to 'evaluate and design scientific enquiry'. It is important new knowledge be developed, directly connected to the procedures of enquiry, its evaluation and its findings quality (OECD, 2016a). Lastly, individuals should 'interpret data and evidence scientifically'. It describes their ability to read, comprehend, interpret and analyze information detected in the various means of scientific literacy, like scientific articles, texts and representations (e.g. diagrams, tables etc.). Moreover, they should be able to assess critically their inferences, developing scientific thought and justification (Norris & Phillips, 2003; OECD, 2016a; Osborne, Erduran, & Simon, 2004).

Finally, the elaboration of these competencies is influenced by persons' 'knowledge' and 'attitudes' (OECD, 2006, 2016a). As for knowledge, students should display their content, procedural and epistemic knowledge (Bybee & McCrae, 2011; Ford & Wargo, 2012; OECD, 2006, 2016a). When it comes to attitudes, individuals' 'interest in science', 'valuing scientific approaches to enquiry' and 'environmental awareness' are described. Through attitudes, persons can acquire and implement their scientific knowledge and are involved in scientific issues (OECD, 2016a).

Scientific literacy indices revealing attitudes towards Science

In order for PISA to detect students' attitudes, there are questions in the questionnaire it administers, which constitute indices that reveal these attitudes (OECD, 2016a).

Enjoyment of Science

It is more likely that individuals learn science when they opt to take part in either curricular or extracurricular scientific activities because they find the process entertaining and not due to the fact that school oblige students to learn science (OECD, 2016b). Enjoyment of science is a way to apprehend whether individuals will get involved in various kinds of activities and it can differ among ages and between genders with boys demonstrating greater enjoyment of science than girls both in OECD countries and Greece (Alexander, Johnson, & Kelley, 2012; OECD, 2016b).

Engagement in scientific activities

Students' questionnaire includes questions that examine the frequency they participate in activities about science. This participation is accomplished both in the framework of school curriculum and outside school. Especially extracurricular activities are a significant index that describes individuals' leisure time habits, giving vital information about educational systems (OECD, 2016b). As for the kind of activities outside the learning environment, the most familiar is watching science TV programmes. Next in the ranking is science-related web sites visits and reading magazines and scientific articles in newspapers with information on scientific issues. Contrarily, the less common activity is the attendance of a science club. Greek students are more likely to devote their free time on scientific activities in comparison with the average OECD countries, while in all countries boys tend to participate in science-related activities to a greater extent (OECD, 2016b; Sofianopoulou, Emvalotis, Pitsia, & Karakolidis, 2017).

It is important to be mentioned that, according to PISA 2015, there is a positive relationship between participation in science-related activities and enjoyment of science. It means that students who are more involved in these activities are more likely to demonstrate a greater enjoyment of science (OECD, 2016b).

General value of Science

In PISA 2006 students' questionnaire involved questions that examine their perceptions of general value of science (OECD, 2009). These questions are about individuals' beliefs about the natural world and the influence of scientific and technological advances on people's living and society's economic conditions (OECD, 2009). Both students in OECD countries and Greek ones believe that science has a key role to society (Hatzinikita, 2010).

Epistemic beliefs

Unlike in 2006, PISA 2015 investigated students' epistemic beliefs. Epistemic or epistemological beliefs seems to be related to students' perceptions of general value of science (Hofer & Pintrich, 2002; OECD, 2016a). Epistemic beliefs as evaluated in PISA are determined as people's perceptions about nature of knowledge and process of knowing (Merk et al., 2018). Furthermore, PISA defines in which way these beliefs are used for the personal understanding of the world (Hofer, 2000; Hofer & Pintrich, 1997, 2002; Windberg, Hofverberg, & Lindfors, 2019).

Hofer and Pintrich (1997) proposed a theoretical approach, according to which epistemic beliefs consist of four dimensions, 'certainty of knowledge', 'simplicity of knowledge', 'source of knowledge' and 'justification for knowing' (Windberg et al., 2019).

The first dimension describes the extent that we believe science forms the body of knowledge. The second one indicates that there are questions about science that have a range of answers in order to be understood. According to the third dimension we tend to support that science can either derive from experts' opinions or from our own personal thinking, while the last one demonstrates a major role experiments have when individuals try to perform activities, test hypotheses and draw conclusions (Mason, Boscolo, Tornatora, & Ronconi, 2013; Windberg et al., 2019).

The first two dimensions refer to nature of knowledge, yet the other two to nature of knowing (Bråten et al., 2014; Sinatra, 2016). Moreover, the last dimension of epistemic beliefs, justification for knowing, can be divided in three other dimensions, and more specifically 'justification by authority', 'personal justification', and 'justification by multiple sources', which is the one that proves the importance of experiments (Bråten et al., 2014).

Finally, it is claimed that epistemic beliefs are influenced by people's experiences in their family, educational and socio-cultural environment and they can evolve from childhood to adulthood (Hofer & Pintrich, 1997; Kuhn, Cheney, & Weinstock, 2000; Schommer, 1994). Focusing on the field of natural sciences, according to what is mentioned in PISA (OECD, 2016b), older students are more likely to understand the complex, tentative and evolving nature of scientific knowledge which can be proven by evidence.

There are specific dimensions PISA uses, in particular students' beliefs about the importance of experiments (justification by multiple sources) and their beliefs about the tentative nature of scientific knowledge (personal justification) (Bråten et al., 2014; OECD, 2016b).

PISA findings indicate that a good many students in OECD countries recognize experimental processes as a way of thinking and grasp the tentative nature of scientific knowledge, yet there are no significant differences between genders (OECD, 2016b).

PURPOSE AND RESEARCH QUESTIONS

The purpose of the current study is to examine which indices constitute preservice teachers' attitudes towards scientific literacy and whether epistemic beliefs contribute to science performance. More specifically, the survey tries to answer to the following research questions:

1. Which indices describe the attitudes towards scientific literacy?
2. Which socio-demographic (gender, age/academic year of studies) and academic factors (high school courses) influence these indices?
3. Do epistemic beliefs affect teachers' science performance?

METHOD

Participants

In the present study participated 186 Primary Education students (36 men and 150 women, M = 22.5 years, S.D. = 4.51) from Greece, attending the two last academic years of their programmes. Six individuals were excluded from the analysis because of the lack of information about their academic profile. Thus, the sample was reduced to 180 students, 35 men and 145 women. Of these, 143 attended a course focused on social sciences and humanities during their studies at high school and the remaining 36 attended a course focused on natural sciences with academic subjects like mathematics, physics, biology, chemistry. In this study the convenience sampling method was used (Bryman, 2016; Creswell, 2012; Given, 2008).

Instrument

All participants completed a questionnaire with questions about socio-demographic and academic characteristics, and questions about students' perceptions and attitudes towards science. All the attitudes questions were derived from the PISA student questionnaire. The main reason was as more indices as possible, used in PISA as well, to be constructed (OECD, 2016a). Cronbach's alpha coefficient was used in order the reliability of the attitudes questions to be measured. Its value was found to be excellent ($\alpha = .917$).

Moreover, in order to examine students' scientific literacy, they had to answer some cognitive science items. For this purpose, all the PISA and TIMSS released items were collected and classified in levels of scientific literacy, according to the standards of the PISA assessment (OECD, 2016a). Based on the difficulty level of the items, 10 different tests were constructed. Each participant completed one of these tests in a random way. The questionnaires were constructed in the LimeSurvey software and they were distributed in electronic form.

Data collection

The survey was conducted in two phases. Firstly, it took place the pilot study, in order mistakes in questions to be detected and the questionnaire to be improved. The main study was conducted by distributing questionnaires in electronic form. For this reason, students were coming to a properly equipped laboratory, with available computers and internet access. The environment of each computer was an open web page with two hyperlinks leading to the questionnaires. As the questionnaires required a password to gain full access, each participant was given one at the beginning of the procedure.

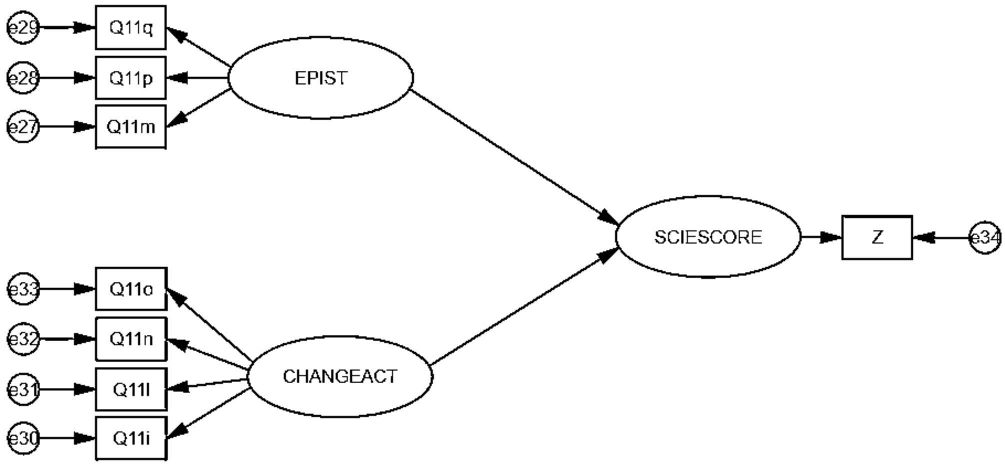
Statistical data analysis

All statistical analyses were performed with the SPSS v.23. Principal component factor analysis was conducted for the whole sample (all the 186 college students) in order to define the indices in accordance with PISA standards. The rotation method used in this analysis was promax rotation, so as to create interrelated factors. The internal consistency was examined by using the Cronbach's alpha coefficient (Field, 2013).

Moreover, the independent t-test was used for the purpose of detecting the differences of the indices means according to the socio-demographic and academic variables (Field, 2013). Kolmogorov-Smirnov and Shapiro-Wilk tests were used in order to check the normal distribution of data. Cases in which normal distribution of data was not met, non-parametric tests were conducted (Field, 2013).

Furthermore, confirmatory factor analysis (CFA) was performed, using AMOS v.18 software. The main goal for the analysis was to determine if the variance on student science achievement can be attributed to the selected indices. The model in Figure 1 (Model 1) was tested so as to examine the relationship between the indices and students' science achievement, which were considered as latent variables. Multivariate normality assumption was met in the data. The estimation method used for the model parameters estimation was the Maximum Likelihood (ML) (Kline, 2015). T-statistic was used to test whether each path coefficient in the model is significant. Also, Cohen's classification was used to interpret the magnitude of each path coefficient in the model (Kline, 2015). Absolute values higher than 0.50, less than 0.10 and between these limits are considered large, small and medium effect sizes, respectively (Kline, 2015). The level of statistical significance was set to $\alpha = .05$.

FIGURE 1



Hypothesized model

RESULTS

Explanatory Factor Analysis (EFA)

A principal component factor analysis was conducted on the 21 items with oblique rotation (promax). The Kayser-Meyer-Olkin measure verified the sampling adequacy for the analysis, KMO = .833. An initial analysis was run to obtain eigenvalues for each factor in the data. Five factors had eigenvalues over Kaiser's criterion of 1 and in combination explained 61.5% of the variance. Table 1 shows the factor loadings after rotation. The items that cluster on the same factor suggest that factor 1 represented the enjoyment of science (JOYSCIE), factor 2 represented the engagement in scientific activities (SCIEACT), factor 3 the epistemic beliefs (EPIST), factor 4 the views on general value of science (GENSCIE) and factor 5 the views on the activities that contribute to changing ideas (CHANGEACT).

The factors of enjoyment of science, engagement in scientific activities, epistemic beliefs and views on general value of science had high values of internal consistency, Cronbach's α = .84, .81, .79 και .73, respectively. However, the factor of views on the activities that contribute to changing ideas had a lower value of internal consistency, Cronbach's α = .64 (Table 1).

Differences in the scientific literacy indices in accordance with gender

The data for both men and women among all indices deviated significantly from normal. Men tend to participate less in science activities (U = 1355, z = -2.721, p = .0035, r = -0.21) and enjoy less their participation (U = 1564, z = -2.440, p = .0075, r = -0.19) than women. However, men's epistemic beliefs (U = 1818.5, z = -1.005, p = .315, r = -0.08), their views on general value of science (U = 1908, z = -1.446, p = .148, r = -0.11) as well as their views on activities that contribute to changing ideas (U = 2236, z = -0.739, p = .460, r = -0.06) did not differ significantly from women's ones (Table 2).

TABLE 1

Summary of items and factor loadings for Promax Orthogonal Five-Factor Solution for the attitude questionnaire (N = *186*)

Item	Factor loading				
	1	2	3	4	5
I like reading about science.	**.853**				
I am happy working on science topics.	**.804**				
I generally have fun when I am learning science topics.	**.771**				
I enjoy acquiring new knowledge in science.	**.748**				
I am interested in learning about science.	**.678**				
Read science magazines or science articles in newspapers.		**.779**			
Borrow or buy books on science topics.		**.754**			
Attend a science club.		**.679**			
Visit web sites about science topics.		**.675**			
Listen to radio programmes about science advancement.		**.669**			
Watch TV programmes about science.		**.642**			
Sometimes scientists change their minds about what is true in science.			**.842**		
The ideas in science books sometimes change.			**.834**		
Ideas in science sometimes change.			**.805**		
Advances in science and technology usually help improve the economy.				**.871**	
Advances in science and technology usually bring social benefits.				**.811**	
Advances in science and technology usually improve people's living conditions.				**.742**	
A good way to know if something is true is to do an experiment.					**.728**
It is good to try experiments more than once to make sure of your findings.					**.707**
Good answers are based on evidence from many different experiments.					**.700**
Science is important for helping us to understand the natural world.					**.593**
α	.84	.81	.79	.73	.64

Note. Boldface indicates highest factor loadings.

TABLE 2

Differences in scientific literacy indices between genders

	Men		**Women**				
Scientific literacy indices	*M*	*SE*	*M*	*SE*	*z*	*p*	*r*
JOYSCIE	2.52	0.12	2.78	0.06	-2.440	.0075	-0.19
SCIEACT	3.39	0.07	3.57	0.04	-2.721	.0035	-0.21
EPIST	2.2	0.15	2.25	0.05	-1.005	.315	-0.08
GENSCIE	2.07	0.09	1.93	0.05	-1.446	.148	-0.11
CHANGEACT	1.91	0.08	1.83	0.04	-0.739	.460	-0.06

Differences in the scientific literacy indices in accordance with high school course courses

The data of both the courses on natural sciences and social sciences/humanities were non-normal among the indices, while for the enjoyment of science both groups did not deviate significantly from normal. Participants from the course on natural sciences get involved more frequently in science activities (U = 1688, z = -1.837, p = .033, r = -0.14), while they enjoy less their participation [$t(168) = 5.083$, $p = 0.000$, $d = 1.08$)] and their epistemic beliefs are less positive ($U = 1788.5$, $z = -1.675$, $p = .047$, $r = -0.13$) than participants from the social sciences/humanities course. However, there was no significant difference between the two groups on their views on both general value of science ($U = 2322$, $z = -0.359$, $p = .719$, $r = -0.03$) and the activities that contribute to changing ideas ($U = 2470.5$, $z = -0.185$, $p = .853$, $r = -0.01$) (Table 3).

TABLE 3

Differences in scientific literacy indices between High School course orientation

	Natural sciences course		Social sciences/Humanities course				
Scientific literacy indices	*M*	*SE*	*M*	*SE*	*z*	*p*	*r*
SCIEACT	3.24	0.08	3.57	0.04	-1.837	.033	-0.14
EPIST	2.28	0.06	3.57	0.04	-1.675	.047	-0.13
GENSCIE	1.95	0.05	1.96	0.07	-0.359	.719	-0.03
CHANGEACT	1.84	0.08	1.86	0.04	-0.185	.853	-0.01

Differences in the scientific literacy indices in accordance with academic year of studies

The data of the fourth year of studies and the data of the third year of studies deviated significantly from normal. There was no significant difference between fourth-year and third-year students' enjoyment of science ($U = 2583.5$, $z = -1.020$, $p = .308$, $r = -0.08$), engagement in science activities ($U = 2491$, $z = -1.11$, $p = .267$, $r = -0.09$), epistemic beliefs ($U = 2520.5$, $z = -0.959$, $p = .338$, $r = -0.07$) and views on general value of science ($U = 2954$, $z = -0.106$, $p = .916$, $r = -0.01$), yet there is significant difference between fourth-year and third-year students' views on activities that contribute to changing ideas ($U = 2098$, $z = -3.349$, $p = .001$, $r = -0.25$), where the third-year students had more positive views than fourth-year students' views, $p = .0005$ (Table 4).

TABLE 4

Differences in scientific literacy indices between the academic years of studies

	Third-Year		Fourth-Year				
Scientific literacy indices	*M*	*SE*	*M*	*SE*	*z*	*p*	*r*
JOYSCIE	2.76	0.07	2.66	0.08	-1.020	.308	-0.08
SCIEACT	3.55	0.04	3.51	0.05	-1.11	.267	-0.09
EPIST	2.27	0.06	2.16	0.1	-0.959	.338	-0.07
GENSCIE	1.96	0.05	1.94	0.07	-0.106	.916	-0.01
CHANGEACT	1.91	0.04	1.67	0.07	-3.349	.0005	-0.25

Confirmatory Factor Analysis (CFA)

The hypothesized model in Figure 1 was tested using AMOS in order to test how much variance on student science achievement can be attributed to the selected indices. Missing values were excluded from the analysis and, also, outliers ($p < 0.05$) according to Mahalanobis distance d, in order to ensure multivariate normality. Model fit was not good [$\chi^2(19) = 36.730$, $p < .05$, RMSEA = .082, CFI = .914, IFI = .918] and, as a result, covariance arrows were set between latent variables (EPIST, CHANGEACT) and between the errors, based on the modification indices. A model with three exogenous latent variables (Model 2) was proposed. Standardized factor loadings of each item validated in the CFA for the three-factor model are shown in Table 5 and Figure 2. The model resulted in satisfactory fit indices [$\chi^2(17) = 22.317$, $p > .05$, RMSEA

= .050, CFI = .977, IFI = .978] (Table 6). All the estimated coefficients in the model were statistically significant at alpha level 0.001.

TABLE 5

Standardized solutions by Confirmatory Factor Analysis for the Two-Factor Model

	Factor	
Item	Epistemic beliefs	Activities that contribute to changing ideas
Q11m	.72	
Q11p	.80	
Q11q	.78	
Q11i		.46
Q11l		.46
Q11n		.71
Q11o		.83

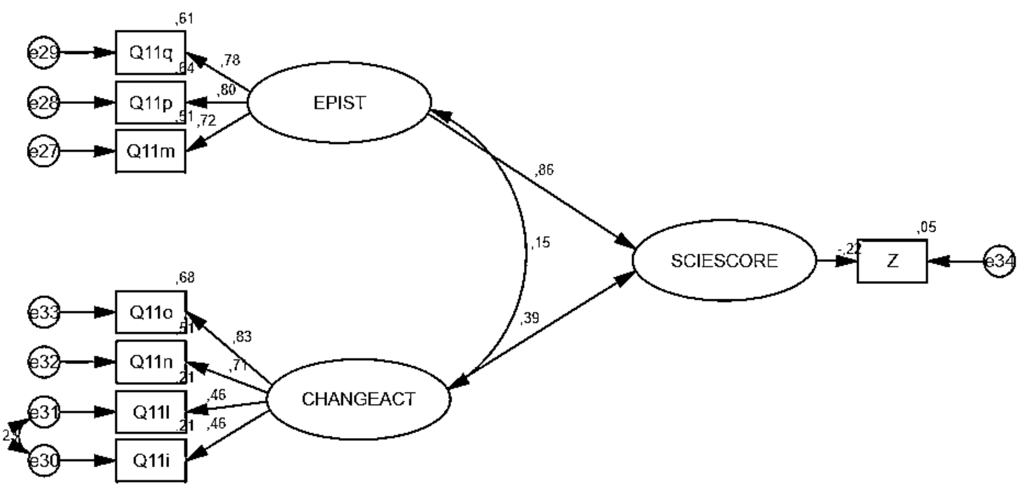
The path coefficients from the exogenous latent variables 'Activities that contribute to Changing Ideas' (.39) and 'Epistemic Beliefs' (.86) (indices included in the model) to science achievement had medium and large effect sizes, respectively (Figure 2). The correlation between the two indices of the model are not high enough, indicating medium effect sizes (Epistemic Beliefs – Activities that contribute to Changing Ideas: .15) (Figure 2).

TABLE 6

Model Fit Statistics

Model	*df*	χ^2	RMSEA	CFI	IFI
Model 1	19	36.730	.082	.914	.918
Model 2	17	22.317**	.050	.977	.978
Note. RMSEA = root mean square error of approximation; CFI = comparative fit index; IFI = incremental fit index. *p < .05, **p > .05					

FIGURE 2



Two-factor Model

DISCUSSION

The purpose of the current study was to investigate the indices that highlight scientific literacy and if epistemic beliefs had an impact on pre-service teachers' science performance.

Scientific literacy indices

Individuals' scientific literacy is described through a range of questions that investigate students' attitudes and views on science. The analysis shows that future teachers' scientific literacy can be determined on the basis of five factors. More specifically, the factors emerged from the explanatory factor analysis was:

- enjoyment of science
- engagement in scientific activities
- epistemic beliefs
- views on general value of science
- views on the activities that contribute to changing ideas.

The findings of the current study are compared, among others, to the findings of PISA. The data are not completely comparable, due to the fact that they refer to different age groups; however, they are used to ascertain the relation of trends.

The findings of PISA 2015, suggests, among others, these indices (OECD, 2016b). Nevertheless, PISA incorporates the questions of epistemic beliefs into one index, describing both students' beliefs about the significance of experiments (justification by multiple sources) and their beliefs about the tentative nature of scientific knowledge (personal justification) (Bråten et al., 2014; OECD, 2016b). The present survey distinguishes the whole index of epistemic beliefs as proposed in PISA into two discrete indices, individuals' epistemic beliefs and their views on the activities that contribute to changing ideas (Bråten & Ferguson, 2014; OECD, 2016b). The former refers to personal justification, while the latter pertains to justification by multiple sources.

Socio-demographic and academic factors that influence scientific literacy indices

Gender

With regard to enjoyment of science and engagement in scientific activities, women are more likely to participate in science activities than men and they tend to enjoy in a greater extent this participation. This finding is opposite to the findings of PISA, were boys are more involved in science activities. The pleasure of engaging in activities in this field can affect individuals' willingness to devote time to these activities. The most common activities to students' preference, according to PISA 2015, are the attendance of scientific TV programmes, the visit of scientific websites and the reading of scientific articles in magazines or newspapers, still the less common is their participation in a science club (OECD, 2016b).

Furthermore, epistemic beliefs describe people's understanding of the nature and origin of science and scientific knowledge (OECD, 2016b). A factor that can differentiate epistemic beliefs is gender. According to Hacıeminoğlu, Ertepınar, Yılmaz-Tüzün, & Çakır (2015), girls demonstrate a better understanding of the tentative nature of science compared with boys. PISA 2015 results in the same findings, as well, where the differences, even small, are in favor of girls, who not only agree that scientific ideas are temporary and can change, but also support empirical research approaches (OECD, 2016b). Similarly, Hofer (2000), in one of her surveys on college students, reached the same conclusion, where men are more likely to believe that scientific knowledge is not subject to change. Contrary to the above findings, the present survey does not show differences in students' epistemic beliefs according to their gender. Moreover, there is no difference in students' views on general value of science and their views on the activities that contribute to changing ideas between women and men.

High School courses

According to High School course, students from a social sciences/humanities course are more 'oriented' to science issues than students from a natural sciences course, due to the fact that they are more engaged in scientific activities and they enjoy more this engagement. Additionally, there is significant difference in students' epistemic beliefs from the perspective of personal justification, where social sciences/humanities course students' epistemic beliefs are more positive than natural sciences course students' epistemic beliefs, while there is no difference in individuals' views on the activities that contribute to changing ideas (justification by multiple sources) and their views on general value of science.

Year of studies

Pre-service teachers do not differentiate in their participation in science activities and their enjoyment when dealing with these activities with regard to the year of their studies.

When it comes to epistemic beliefs, they can change with age as a result of education, where people recognize the complex and tentative nature of scientific knowledge (Hacıeminoğlu et al., 2015; OECD, 2016b). However, there is no significant difference in individuals' epistemic beliefs and views on general value of science of the current research; notwithstanding, third-year students' views on the activities that contribute to changing ideas are more positive than fourth-year students' views. In this point, it is worth noting that people's experiences have a key role in the development of their beliefs, despite the fact that they change with age (Schommer, 1994). Students of the two different years of studies may have different experiences over the years resulting in the generation of any differences.

The impact of scientific literacy indices on pre-service teachers' Science achievements

A confirmatory factor analysis was conducted in this survey, in order to examine the relation among the indices that refers to epistemic beliefs and views on science and to investigate whether these indices affect science achievements or not. As a result, a two-factor model is proposed (Figure 2), according to which, there is a medium size relation between the two indices (epistemic beliefs and views on the activities that contribute to changing ideas).

There are surveys that indicate relation among individuals' beliefs and their science achievements, either positive or negative. Bråten et al. (2014) and Mason et al. (2013) claim that epistemic beliefs affect people's achievements in science. In particular, personal justification, which is relevant to the index of epistemic beliefs of this study, has a negative relation to performance, whereas justification by multiple sources, which appears in this survey as individuals' views on the activities that contribute to changing ideas, are positively related to science performance (Bråten et al., 2014). Furthermore, Greene, Cartiff and Duke (2018), in a meta-analysis they conducted about the relationship between epistemic cognition and academic achievement, found that epistemic cognition was positively correlated with achievement, even if this relationship was small.

Similarly, the findings of the present study reveal that these indices influence pre-service teachers' science achievements. Although epistemic beliefs tend to have a big impact on science achievement, individuals' views on the activities that contribute to changing ideas seem to be weaker affecting their performance. Moreover, other individuals' attitudes, like interest and a greater involvement in scientific activities, can have an impact on beliefs and, in fact, the more interested and active in activities is a person, the better understanding of the nature of scientific knowledge and the nature of knowing they have (Yang et al., 2018).

CONCLUSIONS

In the present study scientific literacy indices were emerged and the factors that affect them were presented. Also, the impact of these indices on science performance was examined.

It is remarkable the fact that women and students from a social sciences/humanities course in high school are more likely to enjoy their participation in science and pursue a bigger engagement in science activities than men and students from a natural sciences course, while surveys, such as PIAAC (constructed by OECD), indicate that men are more scientific literate than women; namely, they perform higher in science than women, something that is observed in Greece, as well.

Taking into consideration the fact that the students mentioned above demonstrate better achievements in science, it could be claimed that they make a greater effort in order to bridge the gap with their fellow students and improve their performance.

Limitations and further research

One limitation emerged during the research process of this study is that the sample was selected with the convenience sampling method. Thus, it cannot be considered as representative for every pre-service teacher and the findings should not be generalized. However, despite this limitation, the trends in scientific charting are emerging.

In the future, a sample collection from more than one department of primary education is proposed and it would be interesting if the relation among each index of scientific literacy, as occurred from the explanatory factor analysis, and their impact on science achievement was examined.

REFERENCES

Alexander, J. M., Johnson, K. E., & Kelley, K. (2012). Longitudinal analysis of the relations between opportunities to learn about science and the development of interests related to science. *Science Education*, *96*(5), 763-786.

Archer-Bradshaw, R. (2017). Teaching for Scientific Literacy? An examination of instructional practices in Secondary Schools in Barbados. *Research in Science Education*, *47*, 67-93.

Bell, R. L. (2006). Perusing Pandora's box: Exploring the what, when, and how of nature of science instruction. In L. B. Flick & N. G. Lederman (Eds.), *Scientific Inquiry and Nature of Science: Implications for teaching, learning, and teacher education* (pp. 427-446). Dordrecht, The Netherlands*:* Kluwer Academic Publishers.

Bråten, I., & Ferguson, L. E. (2014). Investigating cognitive capacity, personality, and epistemic beliefs in relation to science achievement. *Learning and Individual Differences*, *36*, 124-130.

Bråten, I., Ferguson, L. E., Anmarkrud, Ø., Strømsø, H. I., & Brandmo, C. (2014). Modeling relations between students' justification for knowing beliefs in science, motivation for understanding what they read in science, and science achievement. *International Journal of Educational Research*, *66*, 1-12.

Bryman, A. (2016). *Social research methods* (5^{th} Ed.). Oxford: Oxford University Press.

Bybee, W. R. (2006). Scientific Inquiry and scientific teaching. In L. B. Flick & N. G. Lederman (Eds.), *Scientific Inquiry and Nature of Science: Implications for teaching, learning, and teacher education* (pp. 1-12). Dordrecht, The Netherlands*:* Kluwer Academic Publishers.

Bybee, R., & McCrae, B. (2011). Scientific Literacy and student attitudes: Perspectives from PISA 2006 science. *International Journal of Science Education, 33*(1), 7-26.

Chalmers, A. (2013). *What is this thing called Science?* (4th Ed.). Indianapolis: Hackett Publishing Company, Inc.

Creswell, J. W. (2012). *Educational research. Planning, conducting, and evaluating quantitative and qualitative research* (4th ed.). Boston: Pearson Education, Inc.

Duschl, R. (2007). Science Education in three-part harmony: Balancing conceptual, epistemic, and social learning goals. *Review of Research in Education*, *32*, 268-291.

Field, A. (2013). *Discovering statistics using IBM SPSS Statistics* (4th ed.). Los Angeles, London, New Delhi, Singapore, Washington DC: SAGE.

Ford, M. J., & Wargo, B. M. (2012). Dialogic framing of scientific content for conceptual and epistemic understanding. *Science Education*, *96*(3), 369-391.

Given, L. M. (2008). *The Sage encyclopedia of qualitative research methods*. Los Angeles, Calif., London: Sage.

Greene, J. A., Cartiff, B. M., & Duke, R. F. (2018). A meta-analytic review of the relationship between epistemic cognition and academic achievement. *Journal of Educational Psychology, 110*(8), 1084-1111.

Hacıeminoğlu, E., Ertepınar, H., Yılmaz-Tüzün, Ö., & Çakır, H. (2015). Students and school characteristics related to elementary school students' views of the nature of science. *Education 3-13*, *43*(6), 698-719.

Hatzinikita, V. (Ed.) (2010). *PISA 2006 results report for Greece*. Athens: Center for Educational Research.

Hofer, B. K. (2000). Dimensionality and disciplinary differences in personal epistemology. *Contemporary Educational Psychology*, *25*(4), 378-405.

Hofer, B. K., & Pintrich, P. R. (1997). The development of epistemological theories: Beliefs about knowledge and knowing and their relation to learning. *Review of Educational Research, 67*(1), 88-140.

Hofer, B. K., & Pintrich, P. R. (2002). *Personal epistemology: The psychology of beliefs about knowledge and knowing*. Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Khishfe, R. (2017). Consistency of nature of science views across scientific and socio-scientific contexts. *International Journal of Science Education*, *39*(4), 1-30.

Kline, R. B. (2015). *Principles and practice of structural equation modeling* (4th ed.). New York, London: The Guilford Press.

Kuhn, D., Cheney, R., & Weinstock, M. (2000). The development of epistemological understanding. *Cognitive Development*, *15*(3), 309-328.

Lau, K., & Lam, T. Y. (2017). Instructional practices and science performance of 10 top-performing regions in PISA 2015. *International Journal of Science Education*, *39*(15), 2128-2149.

Leblebicioglu, G., Metin, D., Capkinoglu, E., Cetin, P. S., Dogan, E., & Schwartz, R. (2017). Changes in students' views about Nature of Scientific Inquiry at a Science camp. *Science & Education*, *26*, 889-917.

Lederman, N. G. (2007). Nature of Science: Past, present, and future. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of Research on Science Education* (pp. 831-879). Mahwah, NJ: Lawrence Erlbaum Associates.

Lederman, N. G., & Lederman, J. S. (2012). Nature of scientific knowledge and Scientific Inquiry: Building instructional capacity through professional development. In B. J. Fraser, K. J. Tobin, & C. J. McRobbie (Eds.), *Second International Handbook of Science Education* (vol. 1, part III, pp. 711-721). New York: Springer.

Li, M., & Frieze, I. H. (2016). Developing civic engagement in university education: Predicting current and future engagement in community services. *Social Psychology of Education*, *19*(4), 775-792.

Lofaso, A. M. (2006). Does changing the definition of Science solve the establishment clause problem for teaching intelligent design as Science in public schools? Doing an end-run around the constitution. *Pierce Law Review*, *4*(2), 219-278.

Mason, L., Boscolo, P., Tornatora, M. C., & Ronconi, L. (2013). Besides knowledge: A cross-sectional study on the relations between epistemic beliefs, achievement goals, self-beliefs, and achievement in science. *Instructional Science, 41*, 49-79.

Merk, S., Rosman, T., Muis, K. R., Kelava, A., & Bohl, T. (2018). Topic specific epistemic beliefs: Extending the theory of integrated domains in personal epistemology. *Learning and Instruction*, *56*, 84-97.

Michel, H., & Neumann, I. (2016). Nature of Science and Science content learning: The relation between students' Nature of Science understanding and their learning about the concept of energy. *Science & Education*, *25*, 951-975.

Millar, R. (2006). Twenty first century Science: Insights from the design and implementation of a scientific literacy approach in school Science. *International Journal of Science Education, 28*(13), 1499-1521.

Norris, S. P., & Phillips, L. M. (2003). How literacy in its fundamental sense is central to scientific literacy. *Science Education*, *87*(2), 224-240.

OECD. (2006). *Assessing scientific, reading and mathematical literacy: A framework for PISA 2006*. Paris: OECD Publishing.

OECD. (2009). *PISA 2006 Technical report*. Paris: OECD Publishing.

OECD. (2016a). *PISA 2015 assessment and analytical framework: Science, Reading, Mathematic and financial literacy, PISA*. Paris: OECD Publishing.

OECD. (2016b). *PISA 2015 results (Volume I): Excellence and equity in Education, PISA*. Paris: OECD Publishing.

Osborne, J., Erduran, S., & Simon, S. (2004). Enhancing the quality of argumentation in school Science. *Journal of Research in Science Teaching*, *41*(10), 994-1020.

Roberts, D. A. (2007). Scientific literacy/Science literacy. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of Research on Science Education* (pp. 729-780). Mahwah, NJ: Lawrence Erlbaum Associates.

Sadler, T. D., & Zeidler, D. L. (2009). Scientific literacy, PISA, and Socioscientific Discourse: Assessment for progressive aims of Science Education. *Journal of Research in Science Teaching*, *46*(8), 909-921.

Schommer, M. (1994). An emerging conceptualization of epistemological beliefs and their role in learning. In R. Garner & P. A. Alexander (Eds.), *Beliefs about text and instruction with text* (pp.25-40). New Jersey: Lawrence Erlbaum Associates, Inc.

Schwartz, R., Lederman, N. G., & Lederman, J. S. (2008). An instrument to assess views of Scientific Inquiry: The VOSI questionnaire. *Paper presented at the annual meeting of the National Association for Research in Science Teaching, 30 March – 2 April*, Baltimore, MD.

Sinatra, G. M. (2016). Thoughts on knowledge about thinking about knowledge. In J. A. Greene, W. A. Sandoval, & I. Bråten (Eds.), *Handbook of epistemic cognition* (pp. 479-491). New York, NY: Routledge.

Sofianopoulou, X., Emvalotis, A., Pitsia, P., & Karakolidis, A. (2017). *PISA 2015 Results report for the students' achievements evaluation in Greece*. Athens: Institute of Educational Policy.

Windberg, T. M., Hofverberg, A., & Lindfors, M. (2019). Relationships between epistemic beliefs and achievement goals: Developmental trends over grades 5-11. *European Journal of Psychology of Education*, *34*(2), 295-315.

Yang, F. Y., et al. (2018). High-School students' epistemic knowledge of Science and its relation to learner factors in Science learning. *Research in Science Education*, *48*(2), 325-344.