Croatian Journal of Education
Vol.18; No.3/2016, pages: 779-815
Original research paper
Paper submitted: 23rd February 2015
Paper accepted: 6th November 2015
doi: 10.15516/cje.v18i3.1760

Pre-service Primary Teachers' Scientific Knowledge and Attitudes towards Science Learning and Their Influence on the Understanding of the Nature of Science

Jose Javier Verdugo-Perona, Joan-Josep Solaz-Portolés and Vicent Sanjosé-López
Department of Science Education, University of Valencia

Abstract

The present study focused on the knowledge about the nature of science and the question of the extent to which this knowledge could be explained by employing scientific knowledge, as well as attitudes towards science learning. We obtained data from 171 Spanish pre-service primary school teachers on their knowledge about: a) science concepts, b) science process skills, c) the nature of science (that was split into science construction and validation and the role and function of scientific models), and d) their attitudes towards science learning. Quantitative and qualitative analyses provided interesting results: a) there were significant correlations between any pair of scores of conceptual knowledge, procedural knowledge and attitudes towards science learning; b) knowledge of scientific models elaboration and validity was significantly predicted by scientific conceptual knowledge; c) knowledge of science construction and validation was not predicted by scientific knowledge (concepts and processes) or attitudes; d) only 22.7% of all the participants showed coherent ideas aligned with the currently accepted scientific epistemology; and e) having vast scientific knowledge (concepts and processes) and also good attitudes toward science learning did not guarantee correct ideas regarding science construction and scientific models. We conclude that specific content about the nature of science should be explicitly included in pre-service teachers' curricula, as it is not implicitly provided by other types of scientific content.

Key words: *features of working science; prospective elementary teachers; science views; studying science; understanding of science.*

Introduction

Understanding how scientific knowledge is transferred is an inevitable basic objective in science education and has received a lot of attention in the specialised research (Osborne, Collins, Ratcliffe, Miller, & Duschl, 2003). Several reasons justify this objective: it improves the attitude towards science, it clearly reveals scientific methodology as a key factor in the construction of scientific knowledge, and it fosters students' critical thinking and conceptual change through the acceptance of the paradigmatic changes in science (Carey & Smith, 1993). Alan Leshner, Chief Executive Officer of the American Association for the Advancement of Science (AAAS), stated that the understanding of the nature of science (the NOS onwards) is more important than knowing specific details in basic Science education (Perking-Gough, 2007). Also, the Organisation for Economic Co-operation and Development (OECD) recognised the importance of understanding the process which generates scientific knowledge (OECD, 2006).

However, the NOS is rarely addressed in the science classroom (Abd-El-Khalich, Bell, & Lederman, 1998; McComas, Almazroa, & Clough, 1998). In fact, several studies carried out in different countries and at diverse academic levels have shown that textbooks, a fundamental tool in science education, present a distorted image of what the scientific knowledge is and of the way in which science is elaborated (Solaz-Portolés, 2010). But probably most teachers implicitly suppose that teaching science content properly will cause suitable learning of the NOS as well. A question that emerges is: to what extent does an appropriate science content teaching bring about, as a *natural consequence,* suitable NOS knowledge? If the answer to the above question were 'to a great extent', then the NOS would be some kind of a redundant knowledge. If the answer were 'to a small extent', then the NOS should be explicitly taught in the science classrooms, as this specific knowledge has been proved to benefit students in their academic success. For instance, knowing how scientific knowledge grows and/or changes is particularly relevant to students to understand their own difficulties in science learning. In this regard, according to Duschl (1990), students may accept to modify their ideas only if they internalise the nature of the processes involved in scientific research. In a study conducted by Sandoval (2003) evidence was obtained of an interrelationship between understanding scientific concepts and epistemological ideas about the NOS in secondary students. Butler-Songer and Linn (1991), and Šorgo, Usak, Kubiatko, Fančovičova, Prokop, Puhek, Skoda, and Bahar (2014) conducted valuable studies in this vein. The former (Butler-Songer & Linn, 1991) provided evidence that students who believe that scientific ideas can change and who understand that how scientific ideas have been generated is essential for learning these ideas (i.e. those who have a "dynamic vision of science") showed better understanding and generated a more integrated knowledge in Thermodynamics. In the latter work (Šorgo et al., 2014), the authors presented, as a side-effect, a significant correlation between students' scientific knowledge levels (in this case, about genetics and evolution) and their understanding of the NOS.

There is no doubt that teachers' scientific knowledge is strongly related to students' science comprehension. However, concerning the influence of teachers' knowledge about the NOS on students' science understanding, less certainty is attained. Some studies have suggested that students' beliefs about the NOS are more dependent on specific instructional strategies, learning activities and decisions that are made throughout the teaching sequence (Lederman, 1992), than on the teachers' own concepts about the NOS (Brickhouse, 1990; Lederman, 1999; Mellado, 1997; Waters-Adams, 2006). However, the design and implementation of the teachers' pedagogical actions might involve teachers' concepts of the NOS, which would thus indirectly influence students.

Research Questions and Hypotheses

To summarize, students' knowledge about the NOS improves their deep science comprehension and fosters the conceptual change in them when needed. Students' knowledge about the NOS is more influenced by teachers' pedagogical actions than by teachers' knowledge about the NOS. In addition, if the students' knowledge about the NOS were (in part) explained by scientific knowledge (concepts and process skills) and, perhaps by attitudes towards science, making explicit beliefs about the NOS could be (in part) less necessary. Adversely, if this explanation were insufficient, teachers should be trained to be aware of their epistemic beliefs and to teach explicitly about the NOS in their science education classes, in addition to concepts and process skills.

We aimed at answering the following question: To what extent can the knowledge of the NOS be explained by the knowledge of science content and attitudes towards science learning?

This work focuses on particular students - pre-service elementary teachers. Some studies on primary teachers renewed the concern about their poor background scientific knowledge (Appleton, 1996; Verdugo, Solaz-Portolés, & Sanjosé, 2014). However, scientific knowledge has usually been split into conceptual and procedural knowledge. Rittle-Johnson and Alibali (1999) investigated the association between conceptual and procedural knowledge. Their findings highlighted the causal relations between conceptual and procedural knowledge and suggested that conceptual knowledge may have a greater influence on procedural knowledge than reverse. Nevertheless, some research pointed out to low pre-service teachers' knowledge of science process skills (Chabalengula, Mumba, & Mbewe, 2012; ; Foulds & Rowe, 1996)). Concerning attitudes to science, Milner-Bolotin, Antimirova, Noack, and Petrov (2011) found a correlation between students' attitudes to science and their conceptual science learning. The results of Uitto and Kärnä's (2014) study indicate that learning activities focused on procedural knowledge (experimental investigations and observations, pondering upon causes and effects, applying knowledge to everyday life, etc.) are essential to enhance students' attitudes to science learning. A positive and significant correlation between the ability of pre-service primary school teachers to develop and implement science process skills and their attitudes towards science was also found by Downing and Filer (1999).

On the other hand, evidence has been obtained about pre-service and in-service primary teachers' and pre-service and in-service secondary teachers' alarming misconceptions about the NOS (Guisasola & Morentín, 2007; Lederman 1992; Mellado 1997; Sarieddine & Boujaoud, 2014; Vázquez-Alonso, García-Carmona, Manassero-Mas, & Benàssar-Roig, 2013). Research findings have indicated that the teachers' knowledge of science construction and validation as well as their knowledge of the role and function of scientific models proved to be limited and diverse (Dogan & Abd-El-Khalick, 2008; Irez, 2006; Van Driel & Verloop, 1999).

For this reason, we would also like to provide an answer to the question*: Are pre-service primary teachers' ideas on the NOS in line with the current scientific epistemology?*

In the present study we will consider scientific knowledge as a well-defined construct having two components, conceptual and procedural knowledge (at least, as the NOS is considered independently in the present study). In addition, we will consider attitudes towards science learning (emotional component) as an important factor for deep science learning. To our knowledge there has not been much research conducted that has directly and simultaneously examined the relationship between conceptual scientific knowledge, procedural knowledge, attitudes towards science, and knowledge about the NOS among pre-service teachers, by specific quantitative instruments.

From our first research question, the hypothesis is formulated as follows: Pre-service primary teachers' knowledge of science concepts and processes, as well as students' attitudes towards science learning will predict their knowledge about the NOS. Our hypothesis about the second research question is that only pre-service teachers having vast scientific knowledge and good attitudes towards science learning will show coherent epistemic beliefs about the NOS that are close to the currently accepted epistemology of science.

Methodology

Experimental Design

A mixed methodology was carried out in two stages. In the first stage, a transactional or cross-sectional design was used, as measures were taken at once. According to our goals, first we studied the relationship between conceptual knowledge, procedural knowledge, attitudes towards science learning and knowledge about the NOS. Thus, we calculated Pearson's correlations between each pair of scores for these measures. Then we tried to explain the knowledge about the NOS from the scientific knowledge and attitudes by means of proper regression tests. To do that, reliable and independent measures for these variables were needed. A qualitative analysis on the pre-service primary teachers' ideas on the NOS was carried out in the second stage. We conducted semi-structured interviews with a few students having vast science content knowledge and positive attitudes to science learning in order to analyse the consistency of their ideas about science construction and scientific models.

Quantitative Study

Participants

We started with a sample of 210 university students, but we had an experimental mortality of 39 subjects. Hence, the final sample was composed of 171 male and female participants belonging to five different intact groups. All of them were undergraduate students in the third year (out of four) at the Pre-service Teacher Training Faculty in one of the big Spanish universities. Their age typically ranged from 19 to 23 years, with an average age of 21.4 years.

Instruments

We needed our measures to be as independent as possible in order to achieve our goals. It would have been unreasonable to mix concepts and processes and then test the concept-process skills relationship. Usually scientific knowledge tests, as those in PISA (Programme for International Student Assessment) for example, use "mixed" tasks which are suitable to obtain educational information on students' in-context knowledge (i.e. on science education competences). However, when a hypothesised theoretical relationship between certain components has to be studied, independent measures of these components are needed. Instruments chosen in the present work provided independent measures for science concepts and process skills, attitudes and the NOS.

For the science concept knowledge measure we used an instrument developed and validated by Verdugo, Solaz-Portolés, and Sanjosé (2016a) for pre-service elementary teachers (according to Barody, Feil, & Johnson (2007) this instrument includes facts, generalizations and principles). After validation, a shorter second version composing of 30 multiple choice items was proposed (Verdugo, Solaz-Portolés, & Sanjosé, 2016b). Here we used this last version (reliability: KR-20= 0.67) which properly discriminated knowledge of content blocks (natural environment and its preservation, diversity of living beings, health science and personal development, and matter and energy) covered in elementary Science curriculum in Spain (De Pro & Miralles, 2009). All of the 30 items have pure conceptual nature, i.e. no other concepts or process skills were needed to obtain the correct answer. Appendix 1 shows some items from this questionnaire. Scoring was obtained by summing up the 30 item scores: 1 point for the correct answer and 0 for the incorrect answer.

To measure the students' knowledge of science process skills (procedural knowledge associated with intellectual skills) we also utilized a multiple choice questionnaire consisting of 30 items. Content validity and reliability (split-half method: 0.81) was determined by Monde-Monica (2005). Scoring was also obtained by summing up the

30 item scores: 1 point for the correct answer and 0 for the incorrect answer. Appendix 2 shows excerpts from this test.

We have applied a 13-item questionnaire designed in Spain by Ortega, Saura, Mínguez, García de las Bayonas, and Martínez (1992), which tests attitudes towards science learning. This test showed a high reliability (Cronbach's Alpha= 0.86). It uses a five-point Likert-type scale to assess the subject's agreement with the statements provided. The level of agreement, and then the score, varies from "Totally disagree" (1 point) to "Fully agree" (5 points). Six items represent negative attitudes. Scores for these items were reverse (from 5 to 1 point). In our calculations, we converted the mean score for each student (ranging 1-5) into a new score ranging 0-1. Some items of this test may be found in Appendix 3.

To evaluate the understanding of the NOS we used the instrument developed and validated by Vasques-Brandão, Solano-Araujo, Angela-Veit, and Lang de Silveira (2011). This is also a five-point Likert-type scale questionnaire. The original instrument was split into two alternative and equivalent 23-item questionnaires (Form 1 and Form 2) with high reliability (Cronbach's alpha coefficient of 0.87 and 0.86 respectively). We used Form 2, and the Appendix 4 shows excerpts from this questionnaire. Some items are related to conceptions about how science is generated and validated (i.e. goals, fallibility, reliability, etc.), while other items explore conceptions on the role that scientific models have in scientific knowledge (role, function, etc.). Scoring was the same as in the attitudes questionnaire. Due to the structure, we obtained two different scores; one for the conceptions about the scientific knowledge construction and validation (SK) and another one for the conceptions about the role and function of scientific models in science (SM).

Procedure

Instruments were administered at the beginning of the academic year, in two different classroom sessions. In the first session, the science concepts test and the science process skills test were handed in to the participants. Two days later, in the second session, the attitudes and the NOS questionnaires were administered. Both sessions lasted about 90 minutes.

Qualitative study

Participants

A few students were chosen based on their results on the tests of conceptual scientific knowledge, science process skills, attitudes towards science learning and the understanding of the nature of science. These participants obtained high scores (in the third tercile) in the concept and in the processes tests, as well as in attitudes towards science learning in a very coherent way. In addition, they were in the upper half of the SM (conceptions on the role and function of scientific models in science) scores range but, unexpectedly, they were in the lower half of the SK (scientific knowledge construction and validation) scores range. This suggests that they presented contradictory epistemological viewpoints of SK and SM. We tried to identify the nature and reasons for the apparent contradictions by interviewing these students.

Procedure

The results obtained for the SK and SM component of the NOS suggested analysing pre-service teachers' ideas about the NOS in some detail. For clarification purposes, we classified pre-service teachers' ideas in SK and SM according to the three epistemologies proposed by Carey and Smith (1993) and Driver, Leach, Millar, and Scott (1996): phenomenon-based, relation-based, and model-based ideas. In the first one, students believe that science is a kind of "seeking-for-the truth" process and it is built using a well-defined and infallible "method". Scientists' ideas are not relevant as a guidance for science construction and the raw observation is the key-piece for learning how the nature behaves. In the second group students are able to appreciate the role of the hypothesis-testing and they accept that scientists' previous knowledge influences their hypotheses. Even though hypotheses can be refuted and therefore science can change, this is a non-desired effect due to human's limitations and fallibility, but not an inherent factor in science construction. The "genuine" scientific knowledge is cumulative and "erroneous" theories are rejected. In the last group students' ideas are similar to the current scientific epistemology.

Prior to the interview, one of the researchers (JJV) selected those items showing contradictory epistemological viewpoints in the questionnaire of each selected student, i.e. a pair of statements having contradictory information according to an expert point of view. A protocol to conduct the interviews was defined. First, we fostered active participation of the interviewee explaining that he/she was selected based on their good scientific knowledge and attitudes, and that the focus of our interest was to clarify some answers provided in the NOS questionnaire to increase researchers' understanding. In that way we tried to avoid preventing students from changing their answers simply because researchers considered them wrong. Next, a copy of his/her answers to the NOS questionnaire was distributed to each student, encouraging them to remember the reason why they provided them in the past corresponding session. After about 10 minutes, each participant was asked about those "target" contradictory items previously selected by the researchers. The students had to clarify carefully both the meaning of item statement and the answer given to it. They were informed that they were free to support their initial answer or to change it. When the interview was over, the interviewees had the opportunity to make additional comments on any issue they considered relevant. No time limit was imposed on the interviews and each lasted between 20 and 30 minutes.

Results and Discussion

Quantitative Study

Table 1 shows the mean values and standard deviations of the measures obtained from the sample. The NOS measure was split into general knowledge of science construction and validation (SK) and the role and function of scientific models (SM), the main two components of the validated instrument used to assess the NOS. All the scores from the different tests were normalized to values between 0 and 1.

Table 1

Mean values and standard deviations of each of the measures

	NOS	SK	SM	Concepts	Processes	Attitudes
Mean	0.62	0.61	0.63	0.55	0.73	0.78
SD	0.12	0.13	0.17	0.14	0.04	0.13

It should be pointed out that the high mean scores were obtained in procedural measurements (0.73) and in the attitudes towards science learning (0.78). However, despite the characteristics of the test (based on basic scientific concepts in primary education), a lower mean score was obtained for conceptual knowledge (0.55). Therefore, science concepts knowledge of our pre-service teachers was not good on average, as it is apparent in Appleton's study (1996). The procedural scientific knowledge was high in this sample, at variance with the results obtained by Foulds and Rowe (1996), and by Chabalengula, Mumba, and Mbewe (2012). The disagreement is probably due to differences in the instruments used to obtain the data.

Firstly, we computed the Pearson's correlation coefficients between each pair of scores. These correlations are shown in Table 2.

Table 2

Pearson's correlations between each pair of measures

	NOS	SK	SM	Concepts	Processes	Attitudes
NOS	1	0.76**	0.65**	0.11	0.07	0.06
SK		1	0.26**	-0.04	0.06	0.09
SM			1	0.26**	0.08	-0.02
Concepts				1	0.35**	0.31**
Processes					1	0.17*

**Significant correlation at the 0.01 level. *Significant correlation at the 0.05 level.

On the one hand, statistically significant but weak correlations between concept knowledge, procedural knowledge and attitudes have been found. Thus, we obtained a significant and positive correlation between science concepts and science process skills scores, giving support to the scientific knowledge construct. We also obtained a significant positive correlation between attitudes towards science learning and conceptual knowledge, which is consistent with the results of Milner-Bolotin, Antimirova, Noack, and Petrov's study (2011). We notice that there is a significant and positive correlation between attitudes and science process skills scores, which is similar to the one reported in the work of Downing and Filer (1999). On the other hand, a small but statistically significant correlation coefficient between concepts and SM (construction and validation of scientific models) was also found. Nevertheless, SK (scientific knowledge construction and validation) did not significantly correlate with the knowledge or attitudes scores (the truth is that the correlation was non-existent). This result mainly motivated the subsequent interviews.

The trend in educational research is to recognize limitations of linear regression and turn to logistic regression for explaining relationships between a categorical outcome variable and a mixture of continuous and categorical predictors (Peng, Lee, & Ingersoll, 2002). In fact, the research community admits the superiority of logistic regression over linear models (Peng, So, Stage, & John, 2002). In order to examine whether the NOS could be explained using scientific knowledge (conceptual and procedural) and attitudes to science learning, the SM and SK measures were dichotomized. The lower scores (1 and 2) were associated with an incorrect epistemic conception and the higher scores (3, 4, and 5) to the currently accepted epistemic conception of science. After that we carried out different logistic regression analyses for SK and SM. In that way we aimed to predict the correct epistemic knowledge using scientific knowledge and attitudes to learning science. Scores for concept knowledge (C), procedural knowledge (P) and attitudes towards science leaning (A) were taken as predictors. The results are presented in Tables 3 and 4.

Table 3

Logistic regression analysis for SK

Predictor		B	S.E. B	Wald's χ^2	df	p	e^B (odds ratio)
Constant		2.964	1.933	2.351	1	0.125	19.376
Concepts		1.726	1.776	0.945	1	0.331	5.617
Processes		-2.277	2.626	0.752	1	0.386	0.103
Attitudes		-0.784	1.447	0.294	1	0.588	0.456
Test				χ^2	df	p	
Omnibus test of model coefficients							
	Step			1.460	3	0.692	
	Block			1.460	3	0.692	
	Model			1.460	3	0.692	
Goodness of fit test							
	Hosmer & Lemeshow			10.539	8	0.229	

Table 4

Logistic regression analysis for SM

Predictor		B	S.E. B	Wald's χ^2	df	p	e^B (odds ratio)
Constant		-2.236	1.423	2.469	1	0.116	0.107
Concepts		4.378	1.413	9.606	1	0.002	79.696
Processes		0.711	1.908	0.139	1	0.710	2.035
Attitudes		-1.224	1.078	1.289	1	0.256	0.294
Test				χ^2	df	p	
Omnibus test of model coefficients							
	Step			12.446	3	0.006	
	Block			12.446	3	0.006	
	Model			12.446	3	0.006	
Goodness of fit test							
	Hosmer & Lemeshow			2.697	8	0.953	

Omnibus tests of model coefficients lead to the conclusion that the logistic model is more effective than the null model for SM data (p<.01, Table 4), but not in the case of SK data (p>.05, Table 3). According to Table 4, concepts score is the only significant predictor (p<.01) of the SM measure, and the log of the odds of a pre-service teacher for the SM measure is positively related to the concepts score. The Hosmer–Lemeshow (H–L) test (inferential goodness-of-fit test in the Table 4) yields a $\chi^2(8)$ of 2.697 and is insignificant (p > .05), suggesting that the model is sufficiently fit for the data.

A classification table that documents the validity of the predicted probabilities for SM measure is presented in Table 5.

Table 5

The observed and predicted frequencies for SM logistic regression with the cutoff of 0.5

	Predicted		
Observed	Low	High	% Correct
Low	60	32	65.22
High	40	39	49.37
Overall % correct			57.89

According to Table 5, with the cutoff at 0.5, the prediction for pre-service teachers who have a low level of knowledge of the role and function of scientific models (SM) is more accurate than that for those who have a high level of knowledge. Both false high and false low rates are about 40% (45% and 40%, respectively). The overall correction prediction was 57.89%, a slight improvement over the chance level.

Our findings regarding pre-service primary teachers' scientific knowledge and attitudes towards science learning and their influence on the understanding of the nature of science complement the ones obtained by Mugaloglu and Bayram (2010). These authors established a viable structural model of prospective science teachers' NOS views in which attitudes toward science teaching, science process skills, academic achievement, religious values, and economic values explain the NOS views with low predictive power. Our results also complement the research of Cho, Lankford, and Wescott (2011) that shows moderate and significant relationships between students' epistemological beliefs and their knowledge about the NOS (students who have immature epistemological beliefs are more likely to also have immature beliefs of the NOS).

Qualitative Study

Among all the participants, only 37.1% had ideas in line with the currently accepted scientific epistemology, i.e. 62.9% of these participants showed ideas clearly associated with the phenomenon-based or relation-based epistemic positions. Coherence in the NOS ideas, no matter whether these ideas were phenomenon, relation or model-based, emerged in 46.9% of all the participants. Inside the model-based group of students, 61.1% showed high coherence. In the remaining two, phenomenon-based and relation-based groups of epistemic ideas, only 31.1% were consistent enough along the NOS questionnaire. The remaining students moved between phenomenon-based and relation-based epistemic positions in different aspects asked in the instrument.

In summary, only 22.7% of all the participants in the present study, pre-service teachers, showed the NOS coherent ideas aligned with the currently accepted scientific epistemology. In addition, and unexpectedly, 65.8% of the subgroup of participants having high scores in science content knowledge (concepts and processes knowledge) and positive attitudes towards science learning, did not show coherent model-based NOS ideas.

This lack of consistency among the components of knowledge about the NOS motivated a complementary study in order to confirm and analyze the origin of these apparent incongruences. Individual interviews for these brilliant pre-service teachers tried to clarify the origin and nature of these contradictions. Excerpts and comments from the transcripts of some students' interviews are shown below. Firstly, teachers' ideas included in the SK part of the NOS questionnaire were reviewed:

Student #*96:* Phenomenon-based ideas.

I (Interviewer): (reading item 3) *"The starting point for scientific knowledge construction must always be observation and experimentation".*

S (Student): Yes. I chose Strongly agree. (This is a typical belief in the phenomenon-based group of students.)

I: You strongly agreed. Why?

S: Because this is where scientific knowledge must start from… You cannot start from anything different but observation and experimentation. It is not possible to start from another point to build up scientific knowledge. I think that is the only one that exists. (The student sustains that the only existing knowledge comes from observation.)

(…)

Student #97: Phenomenon-based ideas.

I: (reading item 1) *"To enable scientific knowledge to rise from observation and/or experimentation, a scientist must refrain from prior conception". What do you think this statement means?*

S: (…) a scientist, when applying the scientific procedure, has to refrain from prior conceptions in order not to influence the process of research, and… to properly carry out this process of research. (Scientists' prior ideas should be held back in order not to disturb pure observation).

I: Do you mean that a scientist must not have prior conceptions?

S: Of course. He must not have prior conceptions to carry out research, because these prior conceptions can influence the assessment of the result or, even the process of research, waiting for one thing that does not have to be like that. (…)

Student #5: Phenomenon-based ideas.

I: (reading the statement in item 4) *"An important feature of scientific knowledge is its fallibility".*

(…)

S: I strongly disagreed.

I: You think that scientific knowledge cannot fail; it is an important feature…

S: Yes… I think so. When it is established as scientific knowledge, it is presumed that it cannot fail because it is reliable. (Scientific knowledge is infallible by definition).

Student #97: Phenomenon-based ideas.

S: (…)real scientific knowledge could emerge (…).

I: What do you mean by "real scientific knowledge could emerge"?

S: I think that when a scientific process is not followed correctly, with the steps and all the cautions needed, results, no matter how much we wish them to be, are not one hundred per cent reliable.

I: Could you, please, explain to me what you mean when you speak about a process or steps to follow?

S: I mean the scientific method (…). (Scientific method as a very reliable procedure towards the real knowledge).

Pre-service elementary teachers think that observation and experimentation are the very origin of science construction, without any prior knowledge or theories guiding observation and selecting what hypotheses have to be contrasted with in experiments. These beliefs on the way science is built and the infallibility of science when it is "correctly" obtained from the "clearly-defined scientific method" have been found in previous research (Abd-El-Khalick & BouJaoude, 1997; Brickhouse, 1990; Haidar, 1999).

The analysis of some ideas involved in the SM component of the NOS questionnaire was also interesting and provided complementary information on the pre-service elementary teachers' epistemic beliefs:

Student #97: Phenomenon-based ideas.

I: (reading) Item fourteen says: "Scientific models are human constructions: they always originate in the mind of the person who (re)builds them". And you answered there that you agreed.

S: Yes. (…) I understood that scientific models are born in human minds. (…)

I: That is, scientific models are made by human beings.

S: Yes, I think so. There already is science in nature, but human beings are the ones who decode it in some way. (…)

I: Therefore, it might be possible that a part of Science is not created by a human being, yes or no?

S: They don't create it. (Science can exist in nature independently of the human mind).

I: Then, it is an already-made part.

S: Exactly. Scientific models are just a way of understanding what we already have in nature. (Models are imperfect human elaborations to understand nature).

Student #96: Phenomenon-based ideas.

I: (Reading item 22) *"Scientific models should provide exact descriptions of physical systems". Here you said you strongly disagreed.*

S: A scientific model does not have to provide the exact descriptions of a physical system because the scientific model can be, in a concrete system… it does not answer, does not describe it exactly. (…) as a representation, it does not have to describe exactly how a physical system works.

I: Then, you mean that it does not have to give exact descriptions because it is a representation. Do you want to say that it can fail?

S: Yes, it can fail. (…) (Models are fallible because they are only representations of physical systems).

It seems that these teachers believe that science is not "human made" but "nature made", hence, the "correct" scientific knowledge is infallible but we as humans make mistakes when we do not follow the "scientific method" carefully. This could also be the origin of the lack of coherence between the first part (SK) and the second part (SM) concerning the elaboration and validation of scientific models. In this part, the same interviewed students who defend the misconceptions mentioned above had no problem admitting the opposite for models, i.e. their fallibility due to their "human made" nature. Our findings in relation to conceptions about scientific modelling differ from those obtained by Dogan and Abd-El-Khalick (2008). In their study, most science teachers believed that scientific models are copies of reality rather than human inventions because scientists say they are true or because a lot of scientific observations and/or research has shown them to be true.

In summary, the additional data obtained from a few conducted interviews suggested that most teachers who have vast scientific knowledge (concepts and process skills) and good attitudes towards science learning also believe that science is the "real knowledge" of what nature "has" and which humans can discover only by means of careful observation and experimentation. However, due to the limitations of human mind we need models to fit "natural" data into "artificial", fallible and rational schemata (the models). They do not seem to consider scientific models as an important part of science, but as "useful tools" to understand what is happening around us. This is a very interesting result, which might have possible educational implications if it is replicated and gains enough reliability.

Conclusions and Implications

As other researchers found, the conceptual component of the scientific knowledge was the most important one in this study and seemed to connect the other two measures, science process skills and attitudes. The relationship between the attitudes and conceptual and procedural scientific knowledge scores let us suppose that participants coherently integrated cognitive and emotional components of science education, thus giving more reliability to their answers to the different questionnaires administered to them.

We obtained interesting results in the understanding of the NOS measure, that contain items about nature, construction and validation of scientific knowledge (SK), and about nature, function, construction and validation of scientific models (SM). We found a significant and positive, but not a high correlation between the knowledge of scientific concepts and the appropriate understanding of the role of models in science. Furthermore, the probability of achieving a vast knowledge of SM was significantly predicted by the scores in concepts (C), but not by process skills (P) or attitudes (A). In other words, the higher the concepts score, the more likely it is that a pre-service teacher would have a high level of knowledge about SM. It should be pointed out here that the predictive power of the variable was low. On the other hand, participants' vast knowledge of SK did not depend on their scientific knowledge or attitudes. Consequently, our first hypothesis was partially supported, as SM was only related to conceptual scientific knowledge and SK did not appear to depend on any of the independent variables (concepts, processes or attitudes). Thus, apparently, our pre-service teachers' ideas about SK and SM had different epistemic basis.

Based on the qualitative analyses carried out on the pre-service teachers' ideas about the NOS, we can say that most of them had ideas which are not in line with the current scientific epistemology. In fact, only a small percentage of these teachers showed the NOS coherent ideas aligned with the currently accepted scientific epistemology, so only these teachers showed the desired epistemic knowledge for science educators. From the interviews conducted with some brilliant pre-service teachers in our qualitative study, it may be concluded that science training provided them with appropriate conceptual and procedural knowledge and a positive attitude towards the study of science, but not so appropriate conceptions of the NOS, as most teachers showed epistemological contradictions. The thoughts of pre-service teachers who have vast scientific knowledge and good attitudes towards science learning can be summarised as follows: scientific models are human constructions, therefore fallible, and they are not an essential part of scientific knowledge but limited approaches to that knowledge. Instead, science is knowledge that nature already possesses and reveals to us gradually. Human limitations impede the acquisition of the true knowledge offered by nature. Human knowledge about nature does not need to be mediated by models when it has been fully acquired following the (infallible when it is correctly applied) scientific method. Working on this evidence, our second hypothesis became invalid.

Data obtained from quantitative and qualitative analyses in our research allow us to answer our research questions as follows. A component of the knowledge about the NOS, scientific models elaboration and validity (SM), can be significantly predicted by the conceptual scientific knowledge, even though its predictive power is low. However, the other component of the knowledge about the NOS (SK), scientific knowledge construction and validation, cannot be explained by scientific knowledge or attitudes measures at all. On the other hand, only a minority of pre-service teachers involved in this research have shown coherent ideas about the NOS that are in line with the current scientific epistemology.

Therefore, our conclusion is that teachers have to be trained to explicitly include the NOS content in their science education syllabus because this content significantly provides students with deeper comprehension of science, which cannot be indirectly supplied by other types of content. Pre-service teacher training programmes have to include topics such as: science as a way to understand the world around us; science as a creative and tentative endeavour; and scientific methodology, not just as an infallible algorithmic application of determined steps (Chiappetta & Coballa, 2010). Abd-El-Khalick's (2013) work focused on the benefits of the knowledge of the NOS in teacher training. In particular, he underlined that these benefits are two-fold: a) transferring to the student an image of science according to the historical, philosophical, sociological and psychological premises behind it, and b) enabling teachers to develop teaching and learning environment with pedagogical approaches in which scientific research methodologies are applied. Many instructional approaches can be found in literature which enhance teacher's overviews concerning the NOS (Küçük, 2008; Ozgelen, 2012; Schwartz, Lederman, & Crawford, 2004; Smith & Scharmann, 2008). They all share the common denominator of being constructivist approaches, creating opportunities to develop the learning tasks into (guided) scientific research.

Finally, we have to emphasize that our results might not be of general validity due to the lack of random sampling. Other limitations might have been created by the instruments which were used to obtain the measures. Therefore, further research is needed to increase the reliability of these results.

References

Abd-El-Khalick, F. (2013). Teaching with and about nature of science, and science teacher knowledge domains. *Science & Education*, *22*(9), 2087–2107. http://dx.doi.org/10.1007/s11191-012-9520-2

Abd-El-Khalick, F., Bell, R. L., & Lederman, N. G. (1998). The nature of science and instructional practice: Making the unnatural natural. *Science Education*, *82*(4), 417-436. http://dx.doi.org/10.1002/(SICI)1098-237X(199807)82:4<417::AID-SCE1>3.0.CO;2-E

Abd-El-Khalick, F., & Boujaoude, S. (1997). An exploratory study of the knowledge base for science teaching. *Journal of Research in Science Teaching*, *34*(7), 673-699. http://dx.doi.org/10.1002/(SICI)1098-2736(199709)34:7<673::AID-TEA2>3.0.CO;2-J

Appleton, K. (1995). Student teachers' confidence to teach science: Is more science knowledge necessary to improve self-confidence? *International Journal of Science Education*, *17*(3), 357-369. http://dx.doi.org/10.1080/0950069950170307

Baroody, A. J., Feil, Y., & Johnson, A. R. (2007). An alternative reconceptualization of procedural and conceptual knowledge. *Journal for Research in Mathematics Education*, *38*(2), 115–131. http://dx.doi.org/10.2307/30034952

Brickhouse, N. W. (1990). Teachers' beliefs about the nature of science and their relationship to classroom practice. *Journal of Teacher Education*, *41*(3), 53-62. http://dx.doi.org/10.1177/002248719004100307

Butler-Songer, N., & Linn, M. C. (1991). How do students' views of science influence knowledge integration. *Journal of Research in Science Teaching, 28*(9), 761-784. http://dx.doi.org/10.1002/tea.3660280905

Carey, S., & Smith, C. (1993). On understanding the nature of science of scientific knowledge. *Educational Psychologist*, *28*(3), 235-251. http://dx.doi.org/10.1207/s15326985ep2803_4

Chabalengula, V. M., Mumba, F., & Mbewe, S. (2012). How pre-service teachers understand and perform science process skills. *Eurasia Journal of Mathematics, Science and Technology Education, 8*(3), 167-176. http://dx.doi.org/10.12973/eurasia.2012.832a

Chiappetta, E. L., & Koballa Jr, T. R. (2010). *Science instruction in the middle and secondary schools: Developing fundamental knowledge and skills for teaching* (7th Ed.). Columbus OH: Pearson.

Cho, M. -H., Lankford, D. M., & Wescott, D. J. (2011). Exploring the relationships among epistemological beliefs, nature of science, and conceptual change in the learning of evolutionary theory. *Evolution: Education and Outreach*, *4*(2), 313-322. http://dx.doi.org/10.1007/s12052-011-0324-7

De Pro, A., & Miralles, P. (2009). El currículum de conocimiento del medio natural, social y cultural en la educación primaria. *Educatio Siglo XXI*, *27*(1), 59-96.

Dogan, N., & Abd-El-Khalick, F. (2008). Turkish grade 10 students' and science teachers' conceptions of nature of science: A national study. *Journal of Research in Science Teaching*, *45*(10), 1083-1112. http://dx.doi.org/10.1002/tea.20243

Downing, J. E., & Filer, J. D. (1999). Science process skills and attitudes of preservice elementary teachers. *Journal of Elementary Science Education*, *11*(2), 57-64. http://dx.doi.org/10.1007/BF03173838

Driver, R., Leach, J., Millar, R., & Scott, P. (1996). *Young people's images of science.* Buckingham: Open University Press.

Duschl, R. A. (1990). *Restructuring science education: the importance of theories and their development.* New York: Teachers College Press.

Foulds, W., & Rowe, J. (1996). The enhancement of science process skills in primary teacher education students. *Australian Journal of Teacher Education*, *21*(1), 16-23. http://dx.doi.org/10.14221/ajte.1996v21n1.2

Guisasola, J., & Morentin, M. (2007). Comprenden la naturaleza de la ciencia los futuros maestros y maestras de Educación Primaria? *Revista Electrónica de Enseñanza de las Ciencias*, *6*(2), 246-262 /online/. Retrieved on 14th April 2014 from http://www.saum.uvigo.es/reec/volumenes/volumen6/ART2_Vol6_N2.pdf

Haidar, A. H. (1999). Emirates pre-service and in-service teachers' views about the nature of science. *International Journal of Science Education*, *21*(8), 807-822. http://dx.doi.org/10.1080/095006999290309

Küçük, M. (2008). Improving Pre-service Elementary Teachers' Views of the Nature of Science Using Explicit-Reflective Teaching in a Science, Technology and Society Course. *Australian Journal of Teacher Education*, *33*(2) /online/. Retrieved on 16th May 2014 from http://dx.doi.org/10.14221/ajte.2008v33n2.1

Lederman, N. G. (1992). Students' and teachers' conceptions about the nature of science: A review of the research. *Journal of Research in Science Teaching*, *29*(4), 331–359. http://dx.doi.org/10.1002/tea.3660290404

Lederman, N. G. (1999). Teachers' understanding of the nature of science and classroom practice: Factors that facilitate or impede the relationship. *Journal of Research in Science Teaching*, *36*(8), 916–929. http://dx.doi.org/10.1002/(SICI)1098-2736(199910)36:8<916::AID-TEA2>3.0.CO;2-A

McComas, W., Almazroa, H., & Clough, M. P. (1998). The nature of science in science education: An introduction. *Science & Education*, *7*(6), 511-532. http://dx.doi.org/10.1023/A:1008642510402

McComas, W., Clough, M. P., & Almazroa, H. (1998). The role and character of the nature of science in science education. In W. F. McComas (Ed.), *The Nature of Science in Science Education: Rationales and Strategies* (pp. 3-39). Dordrecht, The Netherlands: Kluwer Academic Publishers. http://dx.doi.org/10.1007/0-306-47215-5

Mellado, V. (1997). Preservice teacher's classroom practice and their conceptions of the nature of science. *Science & Education*, *6*(4), 331-354. http://dx.doi.org/10.1023/A:1008674102380

Milner-Bolotin, M., Antimirova, T., Noack, A., & Petrov, A. (2011). Attitudes about science and conceptual physics learning in university introductory physics course. *Physical Reviews Special Topics - Physics Education Research*, *7*(2), 020107 /online/. Retrieved on 17th July 2014 from http://journals.aps.org/prstper/pdf/10.1103/PhysRevSTPER.7.020107

Monde-Monica, K. M. (2005). *Development and validation of a test of integrated science process skills for the further education and training learners.* (Master's thesis). Hatfield, South Africa: University of Pretoria.

Mugaloglu, E. Z., & Bayram, H. (2010). A structural model of prospective science teachers' nature of science views. *Scandinavian Journal of Educational Research*, *54*(6), 597-614. http://dx.doi.org/10.1080/00313831.2010.522848

OECD (Organisation for Economic Cooperation and Development) (2006). *Assessing Scientific, Reading and Mathematical Literacy: A Framework for PISA 2006* /online/. Retrieved on 25th June 2014 from http://www.oecd.org

Ortega, P., Saura, J. P., Mínguez, R., García de las Bayonas, A., & Martínez, D. (1992). Diseño y aplicación de una escala de actitudes hacia el estudio de las ciencias experimentales. *Enseñanza de las Ciencias, 10*(3), 295-303 /online/. Retrieved on 24th August 2013 from http://www.raco.cat/index.php/ensenanza/article/viewFile/39786/93206

Osborne, J., Collins, S., Ratcliffe, M., Millar, R., & Duschl, R. (2003). What "Ideas-about-Science" should be taught in School Science? A Delphi Study of the Expert Community. *Journal of Research in Science Teaching*, *40*(7), 692-720. http://dx.doi.org/10.1002/tea.10105

Ozgelen, S. (2012). Exploring the relationships among epistemological beliefs, metacognitive awareness and nature of science. *International Journal of Environmental & Science Education*, *7*(3), 409-431 /online/. Retrieved on 18th July 2014 from http://www.ijese.com/IJESE_v7n3_Sinan-Ozgelen.pdf

Peng, J. C.-Y., Lee, K. L., & Ingersoll, G. M. (2002). An introduction to logistic regression analysis and reporting. *The Journal of Educational Research*, *96*(1), 3-14. http://dx.doi.org/10.1080/00220670209598786

Peng, J. C.-Y., So, T.-S. H., Stage, F. K., & John, E. P. St. (2002). The use and interpretation of logistic regression in Higher Education Journals: 1988-1999. *Research in Higher Education*, *43*(3), 259-293. http://dx.doi.org/10.1023/A:1014858517172

Perking-Gough, D. (2007). Understanding the Scientific Enterprise: A conversation with Alan Leshner. *Educational Leadership*, *64*(4), 8-15 /online/. Retrieved on 19th January 2014 from http://www.ascd.org/publications/educational-leadership/dec06/vol64/num04/Understanding-the-Scientific-Enterprise@-A-Conversation-with-Alan-Leshner.aspx

Rittel-Johnson, B., & Alibali, M. W. (1999). Conceptual and procedural knowledge of mathematics: Does one lead to the other? *Journal of Educational Psychology*, *91*(1), 175-189. http://dx.doi.org/10.1037/0022-0663.91.1.175

Sandoval, W. A. (2003). Conceptual and epistemic aspects of students' scientific explanations. *The Journal of the Learning Sciences*, *12*(1), 5-51. http://dx.doi.org/10.1207/S15327809JLS1201_2

Sarieddine, D., & Boujaoude, S. (2014). Influence of teachers' conceptions of the nature of science on classroom practice. *Eurasia Journal of Mathematics, Science & Technology Education*, *10*(2), 135-151. http://dx.doi.org/10.12973/eurasia.2014.1024a

Schwartz, R. S., Lederman, N. G., & Crawford, B. A. (2004). Developing views of nature of science in an authentic context: An explicit approach to bridging the gap between nature of science and scientific inquiry. *Science Education*, *88*(4), 610-645. http://dx.doi.org/10.1002/sce.10128

Smith, M. U., & Scharmann, L. (2008). A multi-year program developing an explicit reflective pedagogy for teaching pre-service teachers the nature of science by ostention. *Science & Education, 17*(2), 219–248. http://dx.doi.org/10.1007/s11191-006-9009-y

Solaz-Portolés, J. J. (2010). La naturaleza de la ciencia y los libros de texto: una revisión. *Educación XX1*, *13*(1), 65-80 /online/. Retrieved on 19th January 2013 from http://www.rerce.es/ http://dx.doi.org/10.5944/educxx1.13.1.277

Šorgo, A., Usak, M., Kubiatko, M., Fančovičova, J., Prokop, P., Puhek, M., Skoda, J., & Bahar, M. (2014). A cross-cultural study on freshmen's knowledge of genetics, evolution, and the nature of science. *Journal of Baltic Science Education*, *13*(1), 6-18.

Uitto, A., & Kärnä, P. (2014). Teaching methods enhancing grade nine students' perfomance and attitudes towards biology. In C. P. Constantinou, N. Papadouris, & A. Hadjigeorgiu (Eds.), *E-Book Proceedings of the ESERA 2013 Conference: Science Education Research For Evidence-based Teaching and Coherence in Learning. Part 2* (pp. 67-73). Nicosia, Cyprus: European Science Education Research Association.

Vázquez-Alonso, A., García-Carmona, A., Manassero-Mas, M. A., & Bennàssar-Roig, A. (2013). Spanish secondary-school science teachers' beliefs about Science-Technology-Society (STS) Issues. *Science & Education*, *22*(5), 1191–1218. http://dx.doi.org/10.1007/s11191-012-9440-1

Vasques-Brandão, R., Solano-Araujo, I., Angela-Veit, E., & Lang de Silveira, F. (2011). Validación de un cuestionario para investigar concepciones de profesores sobre ciencia y modelado científico en el contexto de la física. *Revista Electrónica de Investigación en Educación en Ciencias*, *61*(1), 43-61 /online/. Retrieved on 29th January 2013 from http://reiec.sites.exa.unicen.edu.ar/volumen-6-nro-1-2011-1

Verdugo, J. J., Solaz-Portolés, J. J., & Sanjosé, V. (2016a). Development and validation of the first version of a questionnaire for measuring pre-service primary teachers' science content knowledge. *Periódico Tchê Química*, *13*(2), 140-150.

Verdugo, J. J., Solaz-Portolés, J. J., & Sanjosé, V. (2016b). Pre-service Primary School Teachers' Science Content Knowledge: an Instrument for its Assessment. *International Journal of Innovation in Science and Mathematics Education*, *24*(2), 37-51.

Verdugo, J. J., Solaz-Portolés, J. J., & Sanjosé, V. (2015). Spanish pre-service primary teachers' knowledge of science concepts: an instrument for its assessment. *Manuscript submitted for publication.*

Waters-Adams, S. (2006). The relationship between understanding of the nature of science and practice: The influence of teachers' beliefs about education, teaching and learning. *International Journal of Science Education*, *28*(8), 919-944. http://dx.doi.org/10.1080/09500690500498351

Jose Javier Verdugo-Perona
Department of Science Education
University of Valencia
Avda Tarongers, 4. 46022 València, Spain
joverpe@alumni.uv.es

Joan-Josep Solaz-Portolés
Department of Science Education
University of Valencia
Avda Tarongers, 4. 46022 València, Spain
Joan.Solaz@uv.es

Vicent Sanjosé-López
Department of Science Education
University of Valencia
Avda Tarongers, 4. 46022 València, Spain
Vicente.Sanjose@uv.es

Appendix 1

Excerpts from the Test of Conceptual Knowledge

Question	Answer Options*
1. What is the term denoting the movement of the Earth around the Sun?	a) Rotation b) Precession c) Revolution* d) Circumference
11. What is the term denoting the leaves that form the calyx of a flower?	a) Sepals* b) Stamens c) Petals d) Corolla
28. What kind of changes modifies the composition of matter?	a) Physical changes b) Chemical changes* c) Biological changes d) None. Matter does not change.

Appendix 2

Excerpts from the Test of Integrated Science Process Skills

Question	Answer Options*
2. Nomsa wanted to know which of the three types of soil (clay, sandy and loamy), would be best for growing beans. She planted bean seedlings in three pots of the same size, but having different soil types. The pots were placed near a sunny window after pouring the same amount of water in them. The bean plants were examined at the end of ten days. Differences in their growth were recorded. Which factor do you think made a difference in the growth rates of the bean seedlings?	a) The amount of sunlight available. b) The type of the soil used*. c) The temperature of the surroundings. d) The amount of chlorophyll present.
8. A farmer wants to increase the amount of mealies he produces. He decides to study the factors that affect the amount of mealies produced. Which of the following ideas could he test?	a) The greater the amount of mealies produced, the greater the profit for the year. b) The greater the amount of fertilizer used, the greater the amount of mealies produced.* c) The greater the amount of rainfall, the more effective the fertilizer used will be. d) The greater the amount of mealies produced, the lower the cost of mealies.
13. Thembi thinks that the higher the air pressure in a soccer ball, the further it moves when kicked. To investigate this idea, he uses several soccer balls and an air pump with a pressure gauge. How should Thembi test his idea?	a) Kick the soccer balls with different amounts of force from the same point. b) Kick the soccer balls having different air pressure from the same point.* c) Kick the soccer balls having the same air pressure at different angles on the ground. d) Kick the soccer balls having different air pressure from different points on the ground.

Appendix 3

Excerpts from the Scale of Attitudes towards Science Learning

Response options: Totally Disagree (TD); Slightly Agree (SA); Broadly Agree (BA); Strongly Agree (SA); Fully Agree (FA).

Statement		Degree of Agreement				
2	The study of science is burdensome for me because I do not see the value.	TD	SA	BA	SA	FA
9	Everything related to science is interesting to me.	TD	SA	BA	SA	FA
13	I usually disconnect in science lessons.	TD	SA	BA	SA	FA

Appendix 4

Excerpts from the Questionnaire to evaluate the understanding of the Nature of Science

Response options: Strongly Agree (SA); Agree (A); Indecisive (I); Disagree (D); Strongly Disagree (SD)

Statement		Degree of Agreement				
4	An important feature of scientific knowledge is its fallibility.	SA	A	I	D	SD
9	Results from observations and experiments are unquestionable, as they reveal the ways of nature or how it works.	SA	A	I	D	SD
16	Scientific models must be modified when they are not in accordance with the empirical data or with the body of knowledge established.	SA	A	I	D	SD
22	Scientific models should provide exact descriptions of physical systems.	SA	A	I	D	SD

Znanje budućih nastavnika o znanosti, njihovi stavovi o učenju o znanosti i njihov utjecaj na razumijevanje prirode znanosti

Sažetak

Ovo istraživanje bavi se znanjem o prirodi znanosti (NOS), pitanjem mjere u kojoj se to znanje može objasniti preko znanja o znanosti i stavovima o učenju o znanosti. Prikupili smo podatke od 171 studenta nastavničkog smjera u Španjolskoj o njihovu znanju o: a) znanstvenim pojmovima, b) vještinama proučavanja prirodnih znanosti, c) prirodi znanosti (koja je podijeljena na konstrukciju i validaciju znanosti i na ulogu i funkciju znanstvenih modela) i d) njihovim stavovima o učenju znanosti. Kvantitativne i kvalitativne analize donijele su zanimljive rezultate: a) postoje značajne korelacije među parovima rezultata u konceptualnom znanju, proceduralnom znanju i stavovima o učenju znanosti; b) znanje o izradi i valjanosti znanstvenih modela moglo se značajno predvidjeti konceptualnim znanjem o znanosti; c) znanje o konstrukciji i validaciji znanosti nije se predvidjelo znanjem o znanosti (znanstvenim pojmovima i procesima) ili stavovima; d) samo 22,7 % svih sudionika imalo je logične ideje u skladu s trenutno prihvaćenom znanstvenom epistemologijom; e) posjedovanje velikog znanja o znanosti (znanstvenim pojmovima i procesima) i dobri stavovi o učenju o znanosti nisu jamčili točne ideje u vezi s konstrukcijom znanosti i znanstvenih modela. Zaključujemo da bi se specifični sadržaji o prirodi znanosti trebali eksplicitno uključiti u obrazovne kurikule budućih nastavnika, jer nikakvi drugi sadržaji takve specifične sadržaje ne mogu obraditi implicitno.

Ključne riječi: *obilježja praktične znanosti; budući nastavnici; pogledi na znanost; proučavanje znanosti; razumijevanje znanosti.*

Uvod

Razumjeti kako se prenosi znanstveno znanje neizbježan je osnovni cilj obrazovanja u području znanosti zbog čega mu se u specijaliziranim istraživanja posvećuje velika pažnja (Osborne, Collins, Ratcliffe, Miller, i Duschl, 2003). Postoji nekoliko razloga koji opravdavaju taj cilj: on poboljšava stavove o znanosti, jasno otkriva znanstvenu metodologiju kao ključni čimbenik u oblikovanju znanstvenog znanja, što kod učenika stvara osnove kritičkog mišljenja i konceptualne promjene prihvaćanjem paradigmatskih promjena u znanosti (Carey i Smith, 1993). Alan Leshner, izvršni direktor Američkog udruženja za unapređenje znanosti (AAAS), naveo je da je razumijevanje prirode znanosti važnije od pukog znanja o pojedinim detaljima u osnovnom obrazovanju u području znanosti (Perking-Gough, 2007). Organizacija za ekonomsku suradnju i razvoj (OECD) također je prepoznala važnost razumijevanja procesa koji stvara znanstveno znanje (OECD, 2006).

Međutim priroda znanosti (NOS) rijetko je predmet nastave prirodnih znanosti (Abd-El-Khalich, Bell, i Lederman, 1998; McComas, Almazroa, i Clough, 1998). Zapravo nekoliko je istraživanja provedeno u različitim zemljama i na različitim akademskim razinama pokazalo da udžbenici, koji su glavni nastavni alat u obrazovanju u području znanosti, stvaraju krivu sliku o tome što znanstveno znanje zapravo jest i o načinu na koji se znanost obrađuje (Solaz-Portolés, 2010). No vjerojatno većina nastavnika implicitno pretpostavlja da će nastavni proces u kojem se znanost obrađuje na pravilan način dovesti do odgovarajućeg učenja o prirodi znanosti. Pitanje koje se pri tome javlja jest: do koje mjere pravilno poučavanje o znanosti dovodi do odgovarajućeg znanja o prirodi znanosti kao prirodne posljedice tog istog procesa? Ako je odgovor na to pitanje taj da u velikoj mjeri takvo poučavanje dovodi do odgovarajućeg znanja o prirodi znanosti, onda bi se priroda znanosti mogla smatrati nekom vrstom nepotrebnog znanja. Ako je odgovor da je ta mjera mala, onda bi se djecu o prirodi znanosti trebalo poučavati eksplicitno tijekom nastave, jer se pokazalo da je to specifično znanje djeci od velike koristi u akademskom uspjehu. Na primjer znati kako znanstveno znanje raste i/ili se mijenja posebno je važno za učenike da bi mogli razumjeti vlastite poteškoće koje imaju u učenju o znanosti. Vezano uz to, kako je naveo Duschl (1990), učenici mogu prihvatiti potrebu modificiranja svojih ideja samo ako mogu internalizirati prirodu procesa koji se javljaju u znanstvenom istraživanju. U istraživanju koje je proveo Sandoval (2003) dobiveni su dokazi da postoji međusobna povezanost između razumijevanja znanstvenih pojmova i epistemoloških ideja o prirodi znanosti kod srednjoškolaca. Butler-Songer i Linn (1991) i Šorgo, Usak, Kubiatko, Fančovičova, Prokop, Puhek, Skoda, i Bahar (2014) proveli su jako korisna istraživanja o toj temi. Butler-Songer i Linn (1991) pronašli su dokaze za to da su učenici koji smatraju da se znanstvene ideje mogu mijenjati i koji razumiju da je način na koji se znanstvene ideje stvaraju neophodan da bi se te ideje naučile (tj. oni koji imaju „dinamičnu viziju znanosti“) pokazali bolje razumijevanje i stvorili veće integrirano znanje u području termodinamike. U istraživanju koje su proveli Šorgo i sur. (2014) autori su ustanovili, kao dodatni rezultat, značajnu korelaciju između razina znanstvenog znanja učenika (u ovom slučaju znanje o genetici i evoluciji) i njihova razumijevanja prirode znanosti.

Nema sumnje da je znanstveno znanje nastavnika u čvrstoj vezi s načinom na koji učenici razumijevaju znanost. Međutim, kada se radi o utjecaju znanja nastavnika o prirodi znanosti na učenikovo razumijevanje znanosti, tu postoji manja sigurnost.

Neka su istraživanja pokazala da uvjerenja učenika o prirodi znanosti više ovise o specifičnim nastavnim strategijama, nastavnim aktivnostima i odlukama koje se donose tijekom nastavnog procesa (Lederman, 1992) nego o vlastitim poimanju nastavnika o prirodi znanosti (Brickhouse, 1990; Lederman, 1999; Mellado, 1997; Waters-Adams, 2006). Međutim plan i provedba nastavnikovih pedagoških aktivnosti može uključivati i nastavnikovo shvaćanje prirode znanosti, što bi indirektno moglo utjecati na učenike.

Pitanja i hipoteze postavljene u istraživanju

Ukratko, znanje učenika o prirodi znanosti poboljšava njihovo dublje razumijevanje znanosti i stvara konceptualnu promjenu kod njih kada je to potrebno. Na znanje učenika o prirodi znanosti više utječu nastavnikove nastavne strategije nego nastavnikovo znanje o prirodi znanosti. K tome, kad bi se znanje učenika o prirodi znanosti (djelomično) objašnjavalo s pomoću znanstvenog znanja (pojmova i shvaćanja znanstvenih procesa) i možda s pomoću stavova prema znanosti, ne bi bilo tako potrebno stvarati eksplicitna uvjerenja o prirodi znanosti. Suprotno tome, kad bi takvo objašnjenje bilo nedostatno, nastavnici bi trebali imati drugačije obrazovanje koje bi ih učinilo svjesnima svojih epistemoloških uvjerenja i koje bi ih potaknulo da učenike eksplicitno poučavaju o prirodi znanosti tijekom nastavnih sati, uz poučavanje o pojmovima i znanstvenim procesima.

Cilj nam je bio odgovoriti na sljedeće pitanje: *U kojoj se mjeri znanje o prirodi znanosti može objasniti s pomoću znanja o znanstvenim sadržajima i stavovima o učenju znanosti*?

Ovaj rad usredotočen je na posebnu skupinu studenata – onih koji će u budućnosti biti predmetni nastavnici znanosti u osnovnim školama. Neka istraživanja o nastavnicima koji rade u osnovnim školama ponovno su skrenula pažnju na njihovo slabo osnovno znanje o znanosti (Appleton, 1996; Verdugo, Solaz-Portolés, i Sanjosé, 2014). Međutim, znanstveno znanje se obično dijeli na konceptualno i proceduralno znanje. Rittle-Johnson i Alibali (1999) su ispitivali vezu između konceptualnog i proceduralnog znanja. Rezultati njihova istraživanja u središte pažnje stavili su kauzalne odnose između konceptualnog i proceduralnog znanja i uputili na to da konceptualno znanje može imati veći utjecaj na proceduralno znanje, a ne obrnuto. Ipak, neka istraživanja istaknula su da studenti predmetne nastave imaju oskudno znanje o znanstvenim procesima (Chabalengula, Mumba, i Mbewe, 2012; Foulds i Rowe, 1996)). Što se tiče stavova o znanosti, Milner-Bolotin, Antimirova, Noack, i Petrov (2011) pronašli su korelaciju između stavova studenata o znanosti i njihova konceptualnog učenja o znanosti. Rezultati istraživanja koje su proveli Uitto i Kärnä (2014) pokazuju da su aktivnosti učenja koje su usmjerene na proceduralno znanje (eksperimentalno istraživanje i opažanje, razmišljanje o uzrocima i posljedicama, primjena znanja u svakodnevnom životu itd.) neophodne da bi se popravili stavovi učenika o učenju znanosti. Pozitivna i značajna korelacija između sposobnosti budućih nastavnika da razviju i primijene svoje vještine provođenja znanstvenih procesa i njihovih stavova o znanosti također je rezultat istraživanja koje su proveli Downing i Filer (1991).

S druge pak strane postoje dokazi da i budući nastavnici i oni koji već rade i u osnovnim i u srednjim školama imaju zabrinjavajuća pogrešna shvaćanja o prirodi znanosti (Guisasola i Morentín, 2007; Lederman 1992; Mellado 1997; Sarieddine i Boujaoud, 2014; Vázquez-Alonso, García-Carmona, Manassero-Mas, i Benàssar-Roig, 2013). Rezultati istraživanja pokazali su da je znanje nastavnika o konstrukciji i validaciji znanosti, kao i njihovo znanje o ulozi i funkciji znanstvenih modela, ograničeno i raznoliko (Dogan i Abd-El-Khalick, 2008; Irez, 2006; Van Driel i Verloop, 1999;).

Zbog tog razloga bismo također željeli dati odgovor na pitanje: *Jesu li ideje budućih nastavnika o prirodi znanosti u skladu s trenutno prihvaćenom znanstvenom epistemologijom?*

U ovom istraživanju ćemo znanstveno znanje smatrati dobro definiranim konstruktom koji se sastoji od dvije komponente: konceptualnog i proceduralnog znanja (barem od toga, jer se priroda znanosti razmatra neovisno u ovom istraživanju). Osim toga, uzet ćemo u obzir i stavove o učenju o znanosti (emocionalna komponenta) kao važnom čimbeniku za dublje znanje i učenje znanosti. Prema našim spoznajama, ne postoji velik broj provedenih istraživanja koja su izravno i simultano ispitivala vezu između konceptualnog znanstvenog znanja, proceduralnog znanja, stavova o znanosti i znanja o prirodi znanosti kod budućih nastavnika, a primjenom specifičnih kvantitativnih instrumenata.

Iz našeg prvog pitanja postavljenog u istraživanju oblikovana je sljedeća hipoteza: s pomoću znanja budućih osnovnoškolskih nastavnika o znanstvenim pojmovima i procesima, kao i stavova učenika o učenju znanosti, može se predvidjeti znanje učenika o prirodi znanosti. Naša hipoteza vezana uz drugo pitanje postavljeno u istraživanju jest da će samo oni budući nastavnici koji imaju veliko znanje o znanosti i pozitivne stavove o učenju o znanosti pokazati logična epistemološka uvjerenja o prirodi znanosti koja su u tr skladu s trenutno prihvaćenom epistemologijom znanosti.

Metodologija

Eksperimentalni dizajn

Kombinirana metodologija provedena je u dvije faze. U prvoj fazi koristio se transakcijski ili presječni dizajn, jer su se mjerenja prikupljala odjednom. Uzimajući u obzir naše ciljeve, najprije smo ispitali vezu između konceptualnog znanja, proceduralnog znanja, stavova o učenju o znanosti i znanja o prirodi znanosti. S pomoću toga su izračunate Pearsonove korelacije između svakog para rezultata za ova mjerenja. Nakon toga smo pokušali objasniti znanje o prirodi znanosti na temelju znanstvenog znanja i stavova primjenom odgovarajućih regresijskih testova. Da bismo to napravili, bila su potrebna pouzdana i neovisna mjerenja za te varijable. U drugoj fazi provedena je kvalitativna analiza ideja budućih nastavnika o prirodi znanosti. Proveli smo polustrukturirane intervjue s nekoliko studenata koji imaju veliko znanje o znanstvenim sadržajima i pozitivne stavove o učenju o znanosti, a kako bismo analizirali dosljednost njihovih ideja o konstrukciji znanosti i znanstvenim modelima.

Kvantitativna studija

Sudionici

Počeli smo s uzorkom od 210 sveučilišnih studenata, no imali smo osipanje od 39 ispitanika u uzorku. Stoga se konačni uzorak sastojao od 171 studenta muškog i ženskog spola koji su bili svrstani u 5 različitih skupina. Svi studenti bili su dodiplomski studenti na trećoj godini studija (od ukupno četiri godine studija) na Učiteljskom fakultetu jednog velikog španjolskog sveučilišta. Njihova starosna dob bila je u rasponu od 19 do 23 godine, s ukupnom prosječnom dobi od 21,4 godine.

Instrumenti

Da bismo postigli svoj cilj, sva mjerenja trebala su biti što je više moguće neovisna. Bilo bi nerazumno kombinirati pojmove i procese te nakon toga testirati vezu između konceptualnih i proceduralnih vještina. Obično se testovi znanja iz znanosti, poput PISA (*Programme for International Student Assessment*) testova, koriste kombiniranim zadacima koji su prikladni za prikupljanje informacija o učenikovu kontekstualnom znanju (npr. o znanstvenim kompetencijama). Međutim, kada je potrebno proučavati hipotetsku teorijsku vezu između određenih komponenti, potrebna su neovisna mjerenja tih komponenti. Instrumenti koji su se koristili u ovom istraživanju dali su neovisna mjerenja za znanstvene pojmove i procese, stavove i prirodu znanosti.

Za mjerenje znanja o znanstvenim konceptima koristili smo se instrumentom koji su razvili i provjerili Verdugo, Solaz-Portolés i Sanjosé (2016a) za buduće nastavnike (kako tvrde Barody, Feil i Johnson (2007), taj instrument uključuje činjenice, generalizacije i principe). Nakon validacije sastavljena je druga, kraća varijanta, koja se sastojala od 30 pitanja višestrukog izbora (Verdugo, Solaz-Portolés, i Sanjosé, 2016b). Ovdje smo se koristili tom drugom varijantom (pouzdanost: KR-20=0,67) koja jasno pravi razliku između znanja o dijelovima sadržaja (prirodni okoliš i njegovo očuvanje, raznolikost živih bića, zdravstveni odgoj i osobni razvoj, tvar i energija) koji su propisani predmetnim kurikulom za znanost u osnovnoj školi u Španjolskoj (De Pro i Miralles, 2009). Svih 30 pitanja potpuno je konceptualnog tipa, tj. nisu bile potrebne nikakve druge konceptualne ili proceduralne vještine da bi se na njih točno odgovorilo. U Dodatku 1 prikazana su neka pitanja iz ovog upitnika. Rezultat je dobiven zbrojem bodova dobivenih na svih 30 pitanja: po 1 bod za svaki točan odgovor i 0 bodova za svaki netočan odgovor.

Da bi se izmjerilo znanje studenata o znanstvenim procesima (proceduralno znanje povezano s intelektualnim vještinama), koristili smo se također upitnikom koji se sastojao od 30 pitanja višestrukog izbora. Valjanost i pouzdanost sadržaja (*split-half* metoda: 0,81) ispitao je Monde-Monica (2005). Rezultat je također dobiven zbrojem pojedinačnih rezultata za svih 30 pitanja: po 1 bod za svaki točan odgovor i 0 bodova za svaki netočan odgovor. Dodatak 2 pokazuje dijelove tog testa.

Koristili smo se upitnikom koji se sastojao od 13 tvrdnji, a koji su izradili Ortega, Saura, Mínguez, García de las Bayonas i Martínez (1992), a koji ispituje stavove o učenju o znanosti. Taj test pokazao je veliku pouzdanost (Cronbach alpha = 0,86). Koristi se Likertovom skalom od 5 stupnjeva da bi se procijenilo ispitanikovo slaganje s navedenim tvrdnjama. Stupanj slaganja, a zatim i rezultat, varira od „Uopće se ne slažem“ (1 bod) do „Potpuno se slažem“ (5 bodova). Šest tvrdnji predstavlja negativne stavove. Rezultati za te tvrdnje bili su obrnuti (od 5 bodova do 1 boda). Prilikom izračunavanja srednji smo rezultat svakog studenta (u rasponu od 1 do 5) pretvorili u novi rezultat u rasponu od 0 do 1. Neke tvrdnje iz ovog testa mogu se vidjeti u Dodatku 3.

Za procjenjivanje razumijevanja prirode znanosti koristili smo se instrumentom koji su izradili i provjerili Vasques-Brandão, Solano-Araujo, Angela-Veit, Lang de Silveira (2011). To je također upitnik koji se sastoji od Likertove skale od pet stupnjeva. Izvorni je instrument bio podijeljen na dva alternativna i ekvivalentna upitnika od 23 tvrdnje (Obrazac 1 i Obrazac 2) s visokim stupnjem pouzdanosti (Cronbach alfa koeficijent od 0,87 i 0,86 za svaki pojedinačno). Koristili smo se Obrascem 2, a Dodatak 4 pokazuje izvatke iz tog upitnika. Neke su tvrdnje povezane s idejama o stvaranju i validaciji znanosti (tj. ciljevima, pogrešivosti, pouzdanosti itd.), a ostale tvrdnje ispituju ideje o ulozi koju znanstveni modeli imaju u znanstvenom znanju (ulozi, funkciji itd.) Dobivanje rezultata bilo je isto kao i u upitniku o stavovima. S obzirom na strukturu upitnika dobili smo dva različita rezultata: jedan za ideje o konstrukciji i validaciji znanstvenog znanja (SK) i drugi za ideje o ulozi i funkciji znanstvenih modela u znanosti (SM).

Postupak

Instrumenti su se koristili na početku akademske godine, na dva različita nastavna sata. Na prvom satu sudionicima su podijeljeni testovi o znanstvenim pojmovima i znanstvenim procesima. Nakon dva dana, na drugom satu, koristili su se upitnici o stavovima i prirodi znanosti. Oba sata trajala su po 90 minuta.

Kvalitativno istraživanje

Sudionici

Odabrano je nekoliko studenata na temelju rezultata koje su ostvarili na testovima iz konceptualnog znanstvenog znanja, znanstvenih procesa, stavova o učenju o znanosti i razumijevanju prirode znanosti. Ti sudionici postigli su visoke rezultate (u trećem tercilu) na testu iz konceptualnog znanja i procesa, kao i na upitniku o stavovima o učenju o znanosti, na vrlo logičan način. Oni su također bili u gornjoj polovini rezultata na SM testu (ideje o ulozi i funkciji znanstvenih modela u znanosti), ali, neočekivano, bili su u donjoj polovini rezultata na SK testu (konstrukcija i validacija znanstvenog znanja). To upućuje na činjenicu da su dali kontradiktorna epistemološka mišljenja o idejama o ulozi i funkciji znanstvenih modela u znanosti (SM) i konstrukciji i validaciji znanstvenog znanja (SK). Pokušali smo utvrditi prirodu i razloge za očite kontradikcije tako što smo intervjuirali te studente.

Postupak

Rezultati koje smo dobili za SK i SM komponentu prirode znanosti zahtijevali su detaljnu analizu ideja budućih nastavnika o prirodi znanosti. Da bismo dobili bolje objašnjenje, svrstali smo ideje budućih nastavnika u SK i SM skupinu, prema trima epistemologijama koje su predložili Carey i Smith (1993) i Driver, Leach, Millar i Scott (1996): ideje utemeljene na fenomenima, ideje utemeljene na vezama i ideje utemeljene na modelima. U prvoj skupini studenti smatraju da je znanost proces svojevrsne potrage za istinom i da se izgrađuje koristeći se dobro definiranom i nepogrešivom „metodom". Ideje znanstvenika nisu bitne kao vodilje za konstrukciju znanja, a puko promatranje je ključno za učenje o tome kako se priroda ponaša. U drugoj skupini studenti mogu cijeniti ulogu testiranja hipoteza i prihvaćaju da prethodno znanje znanstvenika utječe na njihove hipoteze. Iako se hipoteze mogu odbaciti i tako se znanost može promijeniti, to je neželjeni učinak za koji su odgovorna ljudska ograničenja i pogrešivost, a ne urođeni faktor u konstrukciji znanosti. „Stvarno" znanstveno znanje je kumulativno, a pogrešne teorije se odbacuju. U posljednjoj skupini ideje studenata slične su trenutnoj znanstvenoj epistemologiji.

Prije intervjua jedan je od istraživača (JJV) odabrao one tvrdnje koje su pokazivale kontradiktorna epistemološka stajališta u upitniku svakog odabranog studenta, tj. parove tvrdnji koje su, prema stručnom stajalištu, sadržavale kontradiktorne informacije. Definiran je protokol za provođenje intervjua. Najprije smo s ispitanicima uspostavili aktivno sudjelovanje tako što smo im objasnili da su odabrani zbog svojeg dobrog znanja i stavova o znanosti, zatim da je središte našeg interesa razjasniti neke odgovore koje su dali u upitniku o prirodi znanosti, da bismo poboljšali svoje razumijevanje. Na taj smo način pokušali izbjeći mogućnost da utječemo na studente na način da promijene svoje odgovore samo zato što su ih istraživači smatrali netočnima. Zatim je svakom studentu uručen primjerak njegovih/njezinih odgovora na upitnik o prirodi znanosti, čime ih se pokušalo potaknuti da se sjete razloga zašto su tako odgovorili na pojedina pitanja. Nakon desetak minuta svakog smo ispitanika pitali o onim ciljanim kontradiktornim tvrdnjama koje su istraživači izdvojili.

Studenti su morali pažljivo objasniti i značenje svake tvrdnje i odgovora koji su dali. Rečeno im je da mogu braniti svoj prvi odgovor ili ga promijeniti. Kada je intervju završen, ispitanici su imali priliku dati dodatne komentare o bilo kojoj tvrdnji koju su smatrali važnom. Nisu imali nikakvo vremensko ograničenje za intervjue. Svaki je intevju trajao između 20 i 30 minuta.

Rezultati i rasprava

Kvantitativno istraživanje

Tablica 1 pokazuje srednje vrijednosti i standardnu devijaciju mjerenja dobivenih na uzorku. Mjerenje za prirodu znanosti podijeljeno je na opće znanje o konstrukciji i validaciji znanosti (engl. SK (scientific knowledge) – znanstveno znanje) i na ulogu i funkciju znanstvenih modela (engl. SM – scientific models), tj. na dvije komponente provjerenog instrumenta koji se koristio za procjenu prirode znanosti. Svi rezultati iz različitih testova normalizirani su na vrijednosti između 0 i 1.

Tablica 1

Trebalo bi istaknuti da su visoke srednje vrijednosti dobivene u proceduralnim mjerenjima (0,73) i u stavovima o učenju znanosti (0,78). Međutim, usprkos karakteristikama testa (na temelju znanstvenih pojmova u osnovnoškolskom obrazovanju), slabiji srednji rezultat dobiven je za konceptualno znanje (0,55). Dakle, znanje o znanstvenim pojmovima koje imaju budući nastavnici nije u prosjeku dobro, kako se može vidjeti u Appletonovu istraživanju (1996). Proceduralno znanstveno znanje bilo je veliko u ovom uzorku, što je u suprotnosti s rezultatima koje su dobili Foulds i Rowe (1996) i Chabalengula, Mumba, i Mbewe (2012). Neslaganje rezultata vjerojatno se može pripisati razlikama u instrumentima koji su se koristili za dobivanje podataka.

Najprije smo izračunali Pearsonove koeficijente korelacije između svakog para rezultata. Te korelacije prikazane su u Tablici 2.

Tablica 2

S jedne strane utvrđene su statistički značajne, ali slabe korelacije između konceptualnog znanja, proceduralnog znanja i stavova. Tako smo dobili značajnu i pozitivnu korelaciju između znanstvenih pojmova i rezultata o znanju o znanstvenim procesima, što ide u prilog konstruktu o znanstvenom znanju. Također smo dobili značajnu pozitivnu korelaciju između stavova o učenju o znanosti i konceptualnog znanja, što je u skladu s rezultatima istraživanja koje su proveli Milner-Bolotin, Antimirova, Noack, i Petrov (2011). Uočili smo da postoji značajna i pozitivna korelacija između rezultata o stavovima i znanja o znanstvenim procesima, što je slično korelaciji koju su dobili i Downing i Filer (1999). S druge je pak strane također je utvrđen i malen, ali statistički značajan koeficijent korelacije između pojmova i SM (konstrukcija i validacija znanstvenih modela). Ipak, SK (konstrukcija i validacija znanstvenog znanja) nije bio u značajnoj korelaciji sa znanjem ili stavovima (preciznije, korelacija uopće nije pronađena). Taj je rezultat uglavnom odgovoran za intervjue koji su uslijedili.

Trend u obrazovnim istraživanjima jest prepoznati ograničenja linearne regresije i okrenuti se logističkoj regresiji da bi se objasnile veze između varijable kategoričkih ishoda i kombinacije trajnih i kategoričkih prediktora (Peng, Lee, i Ingersoll, 2002).

Istraživačka zajednica zapravo priznaje nadmoć logističke regresije nad linearnim modelima (Peng, So, Stage, i John, 2002). Da bi se ispitalo može li se priroda znanosti objasniti koristeći se znanstvenim znanjem (konceptualnim i proceduralnim) i stavovima o učenju o znanosti, SM i SK mjerenja bila su prepolovljena. Slabiji rezultati (1 i 2) povezani su s netočnim epistemološkim idejama, a bolji su rezultati (3, 4 i 5) povezani s trenutno prihvaćenom epistemološkom idejom znanosti. Nakon toga smo proveli različite logističke regresijske analize za SK i SM. Na taj smo način pokušali predvidjeti točno epistemološko znanje koristeći se znanstvenim znanjem i stavovima o učenju o znanosti. Rezultati iz konceptualnog znanja (C), proceduralnog znanja (P) i stavova o učenju o znanosti (A) uzeti su kao prediktori. Rezultati su prikazani u Tablicama 3 i 4.

Tablica 3 i 4

Omnibus test koeficijenti modela vode do zaključka da je regresijski model učinkovitiji od nul-modela SM podataka (p<,01, Tablica 4), ali ne u slučaju SK podataka (p>,05, Tablica 3). Prema Tablici 4 rezultat iz pojmova jedini je značajni prediktor (p<,01) SM mjerenja, a logaritam izgleda kod budućih nastavnika što se tiče SM mjerenja je u pozitivnoj vezi s rezultatom iz znanstvenih pojmova. Hosmer-Lemeshowim (H-L) testom (inferencijalni test prilagođenosti u Tablici 4) dobiven je rezultat $\chi^2(8)$ od 2,697 koji nije značajan (p > ,05), što upućuje na to da model nije dovoljno prilagođen podacima.

Klasifikacijska tablica koja dokumentira valjanost predviđenih mogućnosti za SM mjerenje prikazana je u Tablici 5.

Tablica 5

Kako se može vidjeti u Tablici 5, s graničnom vrijednošću od 0,5 predviđanje postotka budućih nastavnika s niskim stupnjem znanja o ulozi i funkciji znanstvenih modela (SM) je točnije nego predviđanje postotka budućih nastavnika koji imaju visok stupanj znanja. I netočne visoke i netočne niske stope predviđanja su oko 40 % (45 % i 40 % za svaku). Ukupna točnost predviđanja bila je 57,89 %, što je malo bolje od stupnja slučajnosti.

Naši rezultati u vezi sa znanjem budućih nastavnika o znanosti i stavovima o učenju o znanosti, kao i njihov utjecaj na razumijevanje prirode znanosti, nadopunjuju rezultate do kojih su došli Mugaloglu i Bayram (2010). Oni su osmislili održiv strukturni model o mišljenjima budućih nastavnika znanosti o prirodi znanosti, u kojem stavovi prema poučavanju o znanosti, znanje o znanstvenim procesima, akademska postignuća, vjerska uvjerenja i ekonomska situacija objašnjavaju gledišta o prirodi znanosti s niskom mogućnošću predviđanja. Naši rezultati također nadopunjuju istraživanje koje su proveli Cho, Lankford, i Wescott (2011), a koje pokazuje umjerene i značajne veze između epistemoloških uvjerenja studenata i njihova znanja o prirodi znanosti (studenti koji imaju nezrela epistemološka uvjerenja vjerojatno će imati i nezrela uvjerenja o prirodi znanosti).

Kvalitativno istraživanje

Od svih ispitanika samo je 37,01 % njih imalo ideje koje su u skladu s trenutno prihvaćenom znanstvenom epistemologijom, tj. 62,9 % tih ispitanika imalo je ideje koje su jasno povezane s epistemološkim gledištima utemeljenima na fenomenima ili vezama. Koherentnost ideja o prirodi znanosti, bez obzira na to jesu li te ideje utemeljene na fenomenima, vezama ili modelima, uočena je kod 46,9 % svih ispitanika. Unutar skupine studenata čije su ideje utemeljene na modelima 61,1 % pokazalo je visok stupanj koherentnosti. U preostale dvije skupine, one čije se ideje temelje na fenomenima i vezama, samo je 31,1 % bilo dovoljno dosljedno u cijelom upitniku o prirodi znanosti. Preostali studenti kretali su se između stajališta utemeljenih na fenomenima i vezama u različitim aspektima o kojima su ispitivani u instrumentu.

Možemo rezimirati da je samo 22,7 % svih sudionika (budućih nastavnika) u ovom istraživanju pokazalo koherentne ideje o prirodi znanosti koje su u skladu s trenutno prihvaćenom znanstvenom epistemologijom. K tome, neočekivano, 65,8 % podskupine sudionika koji su imali visoke rezultate u znanju o znanstvenim sadržajima (znanje o pojmovima i procesima) i pozitivne stavove o učenju o znanosti nije pokazalo logične ideje o prirodi znanosti utemeljene na modelu.

Ta nedosljednost u dijelovima znanja o prirodi znanosti bila je povod za dodatno istraživanje da bi se potvrdilo i analiziralo porijeklo tako očitih nepodudaranja. Pojedinačni intervjui provedeni s ovim briljantnim budućim nastavnicima pokušali su objasniti porijeklo i prirodu takvih kontradiktornosti. Dijelovi i komentari iz prijepisa intervjua provedenih s nekim studentima prikazani su u daljnjem tekstu. Najprije su provjerene ideje budućih nastavnika koje se nalaze u SK dijelu upitnika o prirodi znanosti:

Student br. *96:* Ideje utemeljene na fenomenima.

I (ispitivač): (čitajući tvrdnju br. 3) „Polazna točka konstrukcije znanstvenog znanja uvijek mora biti promatranje i eksperiment.“

S (student): Da. Ja sam odabrao/la odgovor Jako se slažem. *(Ovo je tipično uvjerenje u skupini studenata čije se ideje temelje na fenomenima.)*

I: Jako se slažete s tom tvrdnjom. Zašto?

S: Zato što od toga mora krenuti znanstveno znanje… Ne možete počete ni od čega drugoga osim promatranja i eksperimenta. Nije moguće imati neku drugu polaznu točku da biste počeli graditi znanstveno znanje. Mislim da je to jedina mogućnost. (Student/ica tvrdi da jedino postojeće znanje dolazi od promatranja.)

(…)

Student br. 97: Ideje utemeljene na fenomenima.

I: (čitajući tvrdnju br. 1) *„Da bi omogućio da znanstveno znanje proizlazi iz promatranja i/ili eksperimenta, znanstvenik se mora suzdržati od prethodnih predodžbi.“ Što mislite, što ta tvrdnja znači?*

S: (…) znanstvenik, kada primjenjuje znanstvene postupke, mora se suzdržati od prethodnih predodžbi i ideja da one ne bi utjecale na istraživački proces i… da bi *ispravno proveo istraživački proces.* (Znanstvenik bi svoje prethodne predodžbe trebao zanemariti da ne bi ometale čisto promatranje.)

I: Mislite li da znanstvenik ne smije imati prethodne predodžbe?

S: Naravno. Ne smije imati prethodne predodžbe kada planira provesti istraživanje, jer bi te iste predodžbe mogle utjecati na procjenu rezultata ili čak na provedbu samog istraživanja, čekajući bilo što što ne mora tako izgledati. (…)

Student br. 5: Ideje utemeljene na fenomenima.

I: (čitajući rečenicu u tvrdnji br. 4) „Važno obilježje znanstvenog znanja je njegova pogrešivost.“

(…)

S: Odabrao sam odgovor Uglavnom se ne slažem.

I: Mislite da znanstveno znanje ne može biti pogrešno; to je važno obilježje…

S: Da… mislim. Kada se jednom prihvati kao znanstveno znanje, pretpostavlja se da ne može biti pogrešno jer je pouzdano. (Znanstveno znanje je po definiciji nepogrešivo.)

Student br. 97: Ideje utemeljene na fenomenima.

S: (…) da bi se moglo pojaviti stvarno znanstveno znanje (…).

I: Što mislite kada kažete „stvarno znanstveno znanje“?

S: Mislim da kada se znanstveni proces ne prati na pravi način, po svim koracima i svim potrebnim mjerama opreza, rezultati nisu sto posto pouzdani, bez obzira koliko bismo mi to željeli.

I: Možete li mi, molim vas, objasniti što mislite kada spominjete proces ili korake koji se moraju pratiti?

S: Mislim na znanstvenu metodu (…). (Znanstvena metoda je vrlo pouzdan proces koji vodi stvarnom znanju.)

Budući nastavnici misle da su promatranje i eksperiment jedini izvor konstrukcije znanosti, bez ikakva prethodnog znanja ili teorija koje bi bile vodilje u promatranju i izboru hipoteza koje se u istraživanju moraju suprotstaviti. Ta uvjerenja o tome kako se znanost gradi i o nepogrešivosti znanosti kada se do znanstvenih spoznaja došlo na „pravi način“ primjenom „jasno definirane znanstvene metode“ bila su opažena i u prijašnjim istraživanjima (Abd-El-Khalick i BouJaoude, 1997; Brickhouse, 1990; Haidar, 1999).

Analiza nekih ideja sadržanih u SM dijelu upitnika o prirodi znanosti također je bila zanimljiva i donijela je dodatne informacije o epistemološkim uvjerenjima budućih nastavnika:

Student br. 97: Ideje utemeljene na fenomenima.

I: (čitajući) Tvrdnja br. 14 navodi: „Znanstveni modeli su ljudski konstrukti: uvijek im je polazište u umu osobe koja ih (ponovno) izgrađuje.“ Vi ste odgovorili da se slažete s tom tvrdnjom.

S: Da. (…) Shvatio sam da se znanstveni modeli rađaju u ljudskom umu. (…)

I: Tj. znanstvene modele stvaraju ljudska bića.

S: Da, mislim da je tako. U prirodi već postoji znanost, ali ljudska bića su ta koja tu znanost na neki način interpretiraju. (…)

I: Stoga bi moglo biti moguće da dio znanosti ne stvaraju ljudska bića, da ili ne?

S: Ne stvaraju. (Znanost može postojati u prirodi bez obzira na ljudski um.)

I: Znači, ona je već stvoreni dio.

*S: Upravo tako. Znanstveni modeli su samo način razumijevanja onoga što već imamo u prirodi. (*Modeli su nesavršeni ljudski pokušaji shvaćanja prirode.)

Student br. 96: Ideje utemeljene na fenomenima.

I: (čitajući tvrdnju br. 22) „*Znanstveni modeli trebali bi omogućiti točne opise fizičkih sustava.*“ *Ovdje ste izjavili da se uglavnom ne slažete.*

S: Znanstveni model ne mora omogućiti točne opise fizičkog sustava jer znanstveni model može biti u konkretnom sustavu…ne mora dati odgovor, ne opisuje ga točno. (…) kao prikaz, ne mora točno opisivati kako funkcionira fizički sustav.

I: Dakle, mislite da ne mora dati točan opis zato što je to samo prikaz. Želite li reći da može biti pogrešan?

S: Da, može. (…) (Modeli mogu biti pogrešni zato što su oni samo prikazi fizičkih sustava.)

Čini se da ovi budući nastavnici vjeruju da znanost ne „čine ljudi“, nego je „čini priroda“, pa je stoga „ispravno“ znanstveno znanje nepogrešivo, dok mi ljudi griješimo ako pažljivo ne slijedimo „znanstvenu metodu“. To bi također mogao biti uzrok nedostatku koherentnosti između prvoga dijela (SK) i drugoga dijela (SM) što se tiče razrade i validacije znanstvenih modela. U ovome dijelu isti studenti koje smo intervjuirali, a koji brane u tekstu prije navedene krive predodžbe nisu imali poteškoće priznati upravo suprotno što se tiče modela, tj. njihovu pogrešivost zbog činjenice da ih je stvorio čovjek. Naši rezultati vezani uz ideje o znanstvenom modeliranju razlikuju se od onih do kojih su došli Dogan i Abd-El-Khalick (2008). U njihovu je istraživanju većina nastavnika znanosti smatrala da su znanstveni modeli prije kopije stvarnosti nego ljudski izumi, zato što znanstvenici kažu da su istiniti i/ili su istraživanja pokazala da su istiniti.

Zaključno, dodatni podaci dobiveni iz nekoliko provedenih intervjua upućuju na to da većina nastavnika koja ima veliko znanstveno znanje (pojmovi i procesi) i dobre stavove o učenju o znanosti također vjeruje da je znanost „pravo znanje“ o tome što priroda „ima“ i koje ljudi mogu otkriti samo pažljivim promatranjem i eksperimentiranjem. Međutim, zbog ograničenja ljudskog uma trebamo modele koji mogu uklopiti „prirodne“ podatke u „umjetne“, pogrešive i racionalne sheme (modele). Čini se da oni ne smatraju znanstvene modele tako važnim dijelom znanosti, nego „korisnim alatima“ koji pomažu u razumijevanju onoga što se događa oko nas. To je vrlo zanimljiv rezultat koji bi mogao imati i obrazovne implikacije ako se ponavlja i ako se dokaže njegova pouzdanost.

Zaključci i implikacije

Kako su drugi istraživači zaključili, konceptualni dio znanstvenog znanja bio je najvažniji u ovom istraživanju i činilo se da spaja druga dva mjerenja, znanstvene procese i stavove. Veza između stavova i rezultata u konceptualnom i proceduralnom znanstvenom znanju vodi nas do pretpostavke da su sudionici logički integrirali kognitivnu i emocionalnu komponentu obrazovanja u području znanosti, čineći tako svoje odgovore u raznim upitnicima koji su im podijeljeni pouzdanijima.

Došli smo do zanimljivih rezultata vezanih uz razumijevanje mjerenja prirode znanosti koji sadrže tvrdnje o prirodi, konstrukciji i validaciji znanstvenog znanja (SK) i o prirodi, funkciji, konstrukciji i validaciji znanstvenih modela (SM). Uočili smo značajnu i pozitivnu, iako ne i visoku, korelaciju između znanja o znanstvenim pojmovima i odgovarajućeg razumijevanja uloge modela u znanosti. Nadalje, vjerojatnost usvajanja velikog znanja o znanstvenim modelima bila je značajno predviđena s pomoću rezultata testa iz koncepata, ali ne i postupaka ili stavova. Drugim riječima, što je bolji rezultat na testovima iz pojmova, veća je vjerojatnost da će budući nastavnik imati visok stupanj znanja o znanstvenim modelima. Ovdje bi trebalo naglasiti da je prediktivna moć varijable bila mala. Međutim, dobar rezultat koji su u znanstvenom znanju ostvarili sudionici nije ovisio o njihovu znanstvenom znanju ili stavovima. Tako je naša prva hipoteza djelomično potvrđena, jer su vrijednosti u znanstvenim modelima bile povezane samo s konceptualnim znanstvenim znanjem, a vrijednosti u znanstvenom znanju čini se da nisu ovisile ni o jednoj nezavisnoj varijabli (pojmovima, procesima ili stavovima). Dakle, očito je da su ideje budućih nastavnika o znanstvenom znanju i znanstvenim modelima imale drugačiju epistemološku osnovu.

Na temelju kvalitativne analize ideja budućih nastavnika o prirodi znanosti možemo reći da većina njih ima ideje koje nisu u skladu s trenutno prihvaćenom znanstvenom epistemologijom. U stvari, samo je malen postotak onih koji su pokazali logične ideje o prirodi znanosti u skladu s trenutno prihvaćenom znanstvenom epistemologijom, pa su samo ti nastavnici pokazali epistemološko znanje poželjno kod nastavnika znanosti. Iz intervjua koji su provedeni s nekim briljantnim budućim nastavnicima tijekom našeg kvalitativnog istraživanja može se zaključiti da im je obrazovanje u području znanosti pružilo adekvatno konceptualno i proceduralno znanje i pozitivan stav o učenju o znanosti, ali ne i adekvatne ideje o prirodi znanosti, jer je većina nastavnika pokazala epistemološke kontradiktornosti. Mišljenja budućih nastavnika koji imaju veliko znanstveno znanje i dobar stav o učenju o znanosti mogu se sažeti na sljedeći način: znanstveni modeli su ljudski konstrukti, pa zato mogu biti i pogrešni te nisu neophodan dio znanstvenog znanja, već ograničeni pristupi tom znanju. Umjesto toga, znanost je znanje koje priroda već posjeduje i postupno nam otkriva. Ljudska ograničenja onemogućavaju usvajanje pravog znanja koje priroda nudi. Ljudsko znanje o prirodi ne treba biti posredno, tj. predstavljeno kroz modele, kada je već potpuno usvojeno tijekom praćenja znanstvene metode (nepogrešive kada je točno primijenjena). Obradom tih dokaza naša je druga hipoteza postala nevažeća.

Podaci dobiveni iz kvantitativne i kvalitativne analize u našem istraživanju omogućili su nam da na pitanja koja smo u istraživanju postavili odgovorimo na sljedeći način. Dio znanja o prirodi znanosti, razrada znanstvenih modela i njihova valjanost (SM) mogu se značajno predvidjeti s pomoću konceptualnog znanstvenog znanja, iako je njihova prediktivna moć mala. Međutim, druga komponenta znanja o prirodi znanosti (SK), konstrukcija i validacija znanstvenog znanja, uopće se ne može objasniti znanstvenim znanjem ili mjerenjem stavova. S druge pak strane, samo je manjina budućih nastavnika koji su sudjelovali u ovom istraživanju pokazala koherentne ideje o prirodi znanosti koje su u skladu s trenutno prihvaćenom znanstvenom epistemologijom.

Stoga je naš zaključak da se nastavnici trebaju obrazovati tako da eksplicitno uključuju sadržaje iz prirode znanosti u svoje nastavne planove i programe, jer takvi sadržaji učenicima omogućavaju dublje razumijevanje znanosti kakvo se ne može indirektno omogućiti kroz druge sadržaje. Obrazovni kurikuli za buduće nastavnike trebali bi obuhvaćati teme kao što su: znanost kao način razumijevanja svijeta oko nas; znanost kao kreativni i probni pokušaj; znanstvena metodologija, ne samo kao nepogrešiva algoritamska primjena propisanih koraka (Chiappetta i Coballa, 2010). Rad Abd-El-Khalicka (2013) bio je usredotočen na dobrobit znanja o prirodi znanosti u obrazovanju budućih nastavnika. Točnije, on je naglasio da ta dobrobit može biti dvojaka: a) kada se na studenta prebacuje slika znanosti prema povijesnim, filozofskim, sociološkim i psihološkim premisama i b) kada se nastavnicima omogućava da razviju okružje poučavanja i učenja uz pedagoški pristup u kojemu se primjenjuje metodologija znanstvenog istraživanja. U literaturi se mogu pronaći mnogi nastavni pristupi koji mogu poboljšati nastavnikova gledišta o prirodi znanosti (Küçük, 2008; Ozgelen, 2012; Schwartz, Lederman, i Crawford, 2004; Smith i Scharmann, 2008). Sva ona imaju zajednički nazivnik – svi su ti pristupi konstruktivistički i oni stvaraju mogućnosti za pretvaranje nastavnih zadataka u (vođena) znanstvena istraživanja.

Na kraju moramo naglasiti da naši rezultati možda nemaju opću valjanost zbog nepostojanja slučajnog uzorkovanja. Druga ograničenja mogla su se javiti zbog instrumenata kojima smo se koristili da bismo proveli mjerenja. Zato su potrebna daljnja istraživanja da bi se popravila pouzdanost navedenih rezultata.

Prilozi

Dodatak 1

Izvadak iz Testa o konceptualnom znanju

Pitanje	Mogući odgovori*
1. Koji termin označava kretanje Zemlje oko Sunca?	a) Rotacija b) Precesija c) Revolucija* d) Obodnica
11. Koji termin označava lišće koje sačinjava čašku cvijeta?	a) Lapovi * b) Prašnik c) Latice d) Vjenčić
28. Kakva vrsta promjena modificira sastav tvari?	a) Fizičke promjene b) Kemijske promjene* c) Biološke promjene d) Nikakve. Tvar se ne mijenja.

Dodatak 2

Izvadak iz Testa znanja o integriranim znanstvenim procesima

Pitanje	Mogući odgovori*
2. Nomsa je željela znati koji bi od tri tipa tla (glina, pijesak i ilovača) bio najbolji za uzgoj graha. Posadila je sjeme graha u tri lončanice iste veličine, ali s različitom vrstom tla. Lončanice je stavila kraj prozora s puno sunčeva svjetla nakon što ih je zalila jednakom količinom vode. Nakon deset dana pregledala je biljke graha. Zabilježila je razlike u njihovu rastu. Što mislite, koji je faktor odgovoran za razliku u brzini rasta triju biljki graha?	a) Količina dostupne sunčeve svjetlosti. b) Vrsta tla koja se koristila*. c) Temperatura okoline. d) Količina prisutnog klorofila.
8. Farmer želi povećati količinu kukuruza koji proizvodi. Odlučuje proučiti faktore koji utječu na količinu proizvedenog kukuruza. Koje bi od ovih ideja mogao testirati?	a) Što je veća količina proizvedenog kukuruza, to je veći godišnji profit. b) Što je veća količina korištenog gnojiva, to je veća količina proizvedenog kukuruza. * c) Što je veća količina kiše, to je gnojivo učinkovitije. d) Što je veća količina proizvedenog kukuruza, to je niža cijena kukuruza.
13. Thembi misli da što je veći pritisak zraka u nogometnoj lopti, to se lopta dalje kreće kada se udari nogom. Da bi testirao tu ideju, on upotrebljava nekoliko nogometnih lopti i zračnu pumpu s mjeračem pritiska. Kako bi Thembi trebao testirati svoju ideju?	a) Šutnuti s istog mjesta sve nogometne lopte različitom jačinom. b) Šutnuti s istog mjesta nogometne lopte koje imaju različit pritisak zraka.* c) Šutnuti nogometne lopte s istim pritiskom zraka iz različitih kutova. d) Šutnuti nogometne lopte s različitim pritiskom zraka s različitih mjesta.

Dodatak 3

Izvadak iz Skale stavova o učenju o znanosti

Mogući odgovori: Uopće se ne slažem (UN); Djelomično se slažem (DS); Uglavnom se slažem (US); Jako se slažem (JS); Potpuno se slažem (PS).

	Tvrdnja	Stupanj slaganja				
2	Učenje o znanosti mi je naporno jer ne vidim nikakvu korist u tome.	UN	DS	US	JS	PS
9	Sve što je vezano uz znanost mi je zanimljivo.	UN	DS	US	JS	PS
13	Obično se isključim na nastavi znanosti.	UN	DS	US	JS	PS

Dodatak 4

Izvadak iz Upitnika za procjenu razumijevanja prirode znanosti

Mogući odgovori: Jako se slažem (JS); Slažem se (S); Ne znam (NZ); Ne slažem se (NS); Uopće se ne slažem (UN).

	Tvrdnja	Stupanj slaganja				
4	Važna karakteristika znanstvenog znanja je njegova pogrešivost.	JS	S	NZ	NS	UN
9	Rezultati promatranja i eksperimenata su neupitni, jer otkrivaju način na koji priroda funkcionira.	JS	S	NZ	NS	UN
16	Znanstveni modeli moraju se modificirati kada nisu u skladu s empirijskim podacima ili s već prihvaćenim i dokazanim saznanjima.	JS	S	NZ	NS	UN
22	Znanstveni modeli trebali bi dati točne opise fizičkih sustava.	JS	S	NZ	NS	UN