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ARTIGO

# A LARGE-SCALE SURVEY ON NATURE OF SCIENCE CONCEPTIONS OF THE BRAZILIAN BIOLOGY UNDERGRADUATES AND THE POTENTIALLY ASSOCIATED EDUCATION FACTORS

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**ABSTRACT:** The results of a study on conceptions of the nature of science (NOS) among Biology undergraduate students are presented here. Four factors potentially associated with the conceptions of this public were statistically tested: educational stage, course type (for pre-service biology teachers or biologists-in-training), contact with meta-scientific themes, and participation in science initiation. The participants were 691 students from 14 Brazilian universities, who answered a contextualized questionnaire about research in Ecology. There was no variation in conceptions between the different educational stages neither from contact with meta-scientific themes, nor participation in scientific initiation. Nonetheless, undergraduates attending only teacher-training courses presented less-informed NOS conceptions when compared with two other groups, one formed only by biologists-in-training and the other by a combination of biologists-in-training and teaching-training students. Among the 11 aspects of NOS investigated, the students presented less-informed conceptions about those addressing instrumentation and experimental practices. The discussion was directed to certain implications associated with the scenario presented.
**Keywords:** NOS conceptions. Biologists-in-training. Pre-service teachers.

## UM LEVANTAMENTO EM LARGA ESCALA DAS CONCEPÇÕES DE NATUREZA DA CIÊNCIA DE GRADUANDOS DE BIOLOGIA BRASILEIROS E OS POSSÍVEIS ELEMENTOS FORMATIVOS ASSOCIADOS

**RESUMO:** Descrevemos resultados da investigação de concepções de natureza da ciência (NdC) de graduandos de Biologia. Testamos estatisticamente quatro fatores potencialmente associados às concepções desse público: momento da formação, modalidades da graduação, contato com temas metacientíficos e participação em iniciação científica. Contribuíram com o levantamento 691 estudantes, de 14 universidades brasileiras, os quais responderam a um questionário contextualizado cujo tema é a pesquisa em Ecologia. Nossos resultados sugerem que as concepções não variam entre os diferentes momentos da formação, com o contato com temas metacientíficos e com a participação em uma iniciação científica. Entretanto, os graduandos que cursavam apenas a licenciatura apresentaram concepções de

NdC menos informadas em comparação com os outros dois grupos (um formado só por bacharelandos e outro por bacharelandos e licenciandos). Dentre 11 aspectos de NdC investigados, os estudantes apresentaram concepções menos informadas naqueles relacionados à instrumentação às práticas experimentais. Discutimos algumas das implicações associadas ao panorama apresentado.

**Palavras-chave:** Concepções de natureza da ciência. Formação de cientistas. Formação de professores.

**UN LEVANTAMIENTO EN GRAN ESCALA DE LAS CONCEPCIONES DE NATURALEZA DE LA CIENCIA DE ESTUDIANTES BRASILEÑOS DE PREGRADO DE BIOLOGÍA Y LOS POSIBLES ELEMENTOS FORMATIVOS ASOCIADOS**

**RESUMEN:** Describimos resultados de la investigación de concepción de naturaleza de la ciencia (NdC) de estudiantes de pregrado en Biología. Probamos estadísticamente cuatro factores potencialmente asociados a las concepciones de ese público: momento de la formación, modalidad de licenciatura (formación docente; formación no docente; o formación docente y no docente ao miesmo tiempo), contacto con temas metacientíficos y participación en iniciación científica. Contribuyeron al levantamiento 691 estudiantes, de 14 universidades brasileñas, los cuales contestaron a un cuestionario contextualizado cuyo tema es la investigación en Ecología. Nuestros resultados indican que las concepciones no varían entre los diferentes momentos de la formación, el contacto con temas metacientíficos ni con la participación en iniciación científica. Sin embargo, los estudiantes de pregrado que cursaban solamente la modalidad docente presentaron concepciones de NdC menos informadas en comparación con las de los otros dos grupos (uno formado sólo por los estudiantes de modalidad no docente y otro por estudiantes de modalidad no docente y docente). Entre 11 aspectos de NdC investigados, los estudiantes presentaron concepciones menos informadas en aquellos relacionados a la instrumentación y prácticas experimentales. Discutimos algunas de las implicaciones asociadas al panorama presentado.

**Palabras clave:** Concepciones de naturaleza de la ciencia. Formación de científicos. Formación de profesores.

## INTRODUCTION

The expression *nature of science* (NOS) is strongly associated with the way science works or, rather, how scientists collect, interpret and use data in scientific research, how scientific knowledge is produced and constructed, and what the relationship between these factors and society is. Even though there are variations as to the meaning of NOS (ABD-EL-KHALICK; LEDERMAN, 2000a), there is agreement among some researchers about the main aspects of NOS that are relevant for teaching sciences (MCCOMAS *et al*., 2002). Among the aspects frequently listed as consensual, those outstanding are (i) the empirical character of science, (ii) the absence of a unique scientific method, (iii) the interdependence between science and society, (iv) the role of creativity and collaboration among scientists for the production of knowledge, (v) the tentative character of science, (vi) the use of empirical evidence and logic, and (vii) the correlations between laws and theories (LEDERMAN, 1992; MCCOMAS *et al.,* 2002; LEDERMAN, 2007; PARASKEVOPOULOU; KOLIOPOULOS, 2011; ABD-EL-KHALICK, 2012). Apart from the apparent unanimity perpetuated by these seven aspects of NOS, there are several others, at least 25 according to the systematic review of Azevedo & Scarpa (2017a), that are related to several sciences, and which are not taken into consideration in the assumed consensual point-of-view. Even though, since the mid-1960s there are studies on the insertion of NOS elements into teaching, the combined debate on *which, how and why* NOS aspects need to be taught is relatively recent (AZEVEDO; SCARPA, 2017a).

According to Adúriz-Bravo (2005, p. 04), NOS refers to "*the aggregation of meta-scientific ideas worthwhile for teaching natural science*". The author states that, apart from the imprecision of this definition, there are significant advantages into it, since, when approaching the meta-sciences with non-professionals, it is possible to (i) avoid conflict when distinguishing the various meta-sciences, such as the History and Sociology of Science, (ii) leave associated theoretic schools unspecified, thus allowing for flexibility, and (iii) mobilize a careful selection of those elements that could have a positive impact on teaching.

Notwithstanding the increase over the last years in the number of studies on NOS conceptions (AZEVEDO; SCARPA, 2017a), probably due to the concern with including scientific meta-knowledge at several teaching levels (MCCOMAS; OLSON, 1998; ACEVEDO-DÍAZ, 2005), contemplation and criticism of a consensual NOS viewpoint, as presented by Adúriz-Bravo (2005), Clough (2006), Allchin (2011), Irzik & Nola (2011), Matthews (2012), Martins (2015), and Azevedo & Scarpa (2017a), are, as yet, not widely known[1]. A large part of research on NOS conceptions is still focused on basic-education students' inadequate viewpoints about NOS aspects, and on how scientific education could contribute to the maturation of these conceptions (LEDERMAN, 1992). There is also an increasing number of studies dedicated to investigating NOS conceptions among active teachers or those in preparation (SHAPIRO, 1996; TOSUN, 2000; ABD-EL-KHALICK; LEDERMAN, 2000a; ACEVEDO-DÍAZ; ACEVEDO-ROMERO, 2002; AKERSON *et al*., 2006; BELL *et al*., 2011) (AZEVEDO; SCARPA, 2017a).

Furthermore, researchers have tried to understand whether there is a global pattern related to students' NOS conceptions, or whether regional and cultural factors are capable of exerting a certain influence here. Even though certain authors state that NOS conceptions taken as naïve[2] comprise a global tendency, it has been demonstrated that this is not the case (LEDERMAN, 1992). Dogan & Abd-El-Khalick (2008), for example, compared the NOS conceptions of more than 2.000 students from various regions of Turkey and noted that those students from rural areas were more naïve than those from urban areas. A survey of conceptions among Korean students indicated a tendency of presenting a scientific viewpoint directed towards progress and development (KANG *et al*., 2005). This was also the case in other Asian countries (KAWASAKI, 1996). Notwithstanding the growth of research on NOS conceptions over the last few years in Brazil (e.g. TEIXEIRA *et al*., 2001; TAVARES, 2006; TEIXEIRA *et al*., 2009), these are rather scarce, especially on a large scale, as shown in a systematic review by Azevedo & Scarpa (2017a), who analyzed 396 articles published up to February, 2015, on the Science Education journals.

## Comparison between the NOS conceptions of the different groups and survey reliability

Considering that research on NOS conceptions started around 1960 (LEDERMAN, 1992; AZEVEDO; SCARPA, 2017a), the interest in comparing NOS conceptions between different groups of students (especially those outside basic education) and professionals, is relatively recent. In a survey among university students, Jehng *et al*. (1993) noted that students from the courses of social sciences, art, and humanities are more prone to accept the fact that knowledge is uncertain when compared with those studying natural sciences, engineering and management. Along the same line, Liu & Tsai (2008), when appraising 220 university students, deduced that those from areas related to natural sciences presented a more naïve viewpoint on cultural aspects and the role of theories in the construction of knowledge when compared to students from other areas.

Surveys on NOS conceptions and the comparison between different groups are relevant because exposing contrasts facilitates the establishment of possible strategies towards their improvement. Numerous studies focused on investigating conceptions in basic education are mainly focuses on creating ways of comparing groups of students from different cultures and prone to distinct teaching approaches (PARK *et al*., 2013). Nonetheless, at the undergraduate level, the NOS conceptions studies are mainly directed only towards pre-service teachers, furthermore factors that could be related to the conceptions encountered are rarely investigated (AZEVEDO; SCARPA, 2017a).

Few studies have been focused on identifying NOS conceptions among scientists (POMEROY, 1993; PETRUCCI, 2001; WONG; HODSON, 2009) and university students who intend to follow traditionally scientific careers (FELDMAN *et al*., 2009; FELDMAN *et al*., 2013), e.g., Biology, Physics and Chemistry. Investigating NOS conceptions among the latter is relevant in order to identify the way this group conceives the construction of knowledge, as well as to indicate how certain myths could be rooted in the academic environment (HARDING; HARE, 2000; FELDMAN *et al*., 2013). The lack of attention given by researchers to science teaching for this public

(DELAMONT; ATKINSON, 2001) has resulted in few studies about this subject. Apart from basic education and courses for pre-service teachers, the few surveys that do exist have revealed appreciable variation in NOS conceptions.

When comparing the conceptions of scientists and teachers, Deborah Pomeroy (1993) found heterogeneity among scientists, but a significant number of views considered empiricists. Schwartz and Lederman (2008) reported differences between NOS conceptions according to the research area of the participants (Physics, Biology or Chemistry) but indicated that more than 65% of these participants recognized the role of creativity in the work of scientists as opposed to the view of science based strictly on empirical data. Bayir, Cakici and Ertas (2014) investigated scientists NOS conceptions from different areas (such as Social Sciences and Natural Sciences) and concluded the NOS conceptions are not related to the research study area, since the authors stated there is a balance between NOS conceptions among the analyzed groups. In all these studies, researchers invited others to invest their efforts in researching NOS conceptions of future or active scientists, mainly because of the need for comparative investigations to dialogue. Such an analysis becomes even more urgent considering that many of the professors active in university courses involved in scientist and teacher training come from strictly conceptual courses that, while very often deprived of reflection on NOS aspects, are endowed with potentially less-informed NOS conceptions.[3]

## Research questions

In the face of the scenario presented, and considering the gap in the Brazilian context of large-scale-surveys on NOS conceptions and investigation that establishes correlations between these conceptions and possible pertinent factors, the aim of our research was to reply to two questions.

The first of these questions is *(A) What are the factors related to the education of biological science undergraduates that could have any influence on the NOS conceptions of this group?* In response, four possible factors (our predictive variables) were investigated, as presented below with the respective hypotheses and predictions:

(i) Educational stage: it was expected that the educational stage (an expression used here to differentiate undergraduates who are at the beginning of the course from those at the end) would be a factor that could influence NOS conceptions, with advanced students presenting better-informed conceptions.

(ii) Course type: regarding studies that indicate differences between students and scientists from the various areas of knowledge, we expected to find differences among course type in biology courses (those for pre-service biology teachers *versus* those for biologists-in-training), and also expected that pre-service biology teachers would present better-informed NOS conceptions when compared to biologists-in-training due to the presence of more subjects related to Human Sciences within their course.

(iii) Contact with meta-scientific themes in undergraduate disciplines: it was expected that greater contact with themes related to the epistemology of science would contribute to the development of better-informed NOS conceptions.

(iv) Participation in science initiation (SI): it was also expected that contact with the production of knowledge, made plausible or strengthened through SI, would contribute to the development of better-informed NOS conceptions.

The second question is *(B) Are there any differences in the understanding of certain aspects of the nature of science?* We are interested in identifying if these differences were the same between pre-service teachers and biologists-in-training.

## METHODS

### Data collection

Data collection was only possible due to voluntary contribution by professors of various universities spread throughout Brazil who conceded time during the class for students to participate in this research. Although an electronic questionnaire could have a potentially higher reach, he authors' option was to receive replies to printed questionnaires, since it was believed that adherence would be higher. Thus, 58 professors of public and private universities, spread throughout various regions of Brazil, were contacted through the internet and were informed about the aims of the research. Of the 58, 34 returned the contact and 16 put the application into practice. Due to the decision to apply a printed questionnaire, as well as the time available for data collection, not all of the regions were contemplated in the sample. The contacted universities from the mid-west region, for example, did not make contact in time. Even so, due to the large adhesion obtained, the data exploited in the present study can be considered significant. In most of the institutions, the application was undertaken in the time agreed upon with the professors (around 45 minutes). In some of them, the printed questionnaires were sent by mail.

Student participation in the research was voluntary and all who agreed to do so signed a free and informed consent form printed on the first page of the formal document, informing the aims of the survey and assuring non-disclosure of their information and response. The research was approved by the Committee of Ethics and Research of the Biosciences Institute of the University of São Paulo (Code1.133.412) according to instructions from the *Plataforma Brasil*.[4] The respondents also received written instructions about filling in the questionnaire and recommendations to reply in an anonymous and individual manner.

### Description of the sample

Questionnaires were applied in 14 universities, 78.6% pertaining to the southeast, 7% to the northeast, 7% to the north and 7% to the south. Of them, 78% were public institutions and 22% were private ones. The 691 valid questionnaires received were answered by biology undergraduate students (in courses for pre-service biology teachers and for biologists-in-training). The questionnaires left entirely blank (only 4) or with more than 15% of the answers erased or incomplete were discarded, as were the questionnaires from students who had previously graduated from another course (only 6). Among the respondents, 65% were women, 34% men and 1% opted not to declare their genre at birth. Regarding age, 51% were between 16 and 20 years-old, 41% between 21 and 25, and 8% between 26 and 41. Around 58% of the students were at the beginning of the undergraduate course(up to the 3rd semester), and 42% were at the end (having completed more than 6 semesters) (Table 1).

**Table 1** – Characteristics of the universities and students comprising the sample.

| *University* | *Region* | *Type* | *Number of participating students* | *Number of students initiating college* | *Number of students at the end of college* |
|---|---|---|---|---|---|
| 1 | Southeast | Public | 93 | 93 | 0 |
| 2 | Southeast | Public | 72 | 31 | 41 |
| 3 | South | Public | 71 | 31 | 40 |
| 4 | Southeast | Public | 68 | 49 | 19 |
| 5 | Southeast | Public | 52 | 18 | 34 |
| 6 | Southeast | Public | 49 | 26 | 23 |
| 7 | North | Public | 49 | 21 | 28 |
| 8 | Southeast | Public | 46 | 39 | 7 |
| 9 | Northeast | Public | 42 | 22 | 20 |
| 10 | Southeast | Public | 40 | 0 | 40 |
| 11 | Southeast | Private | 36 | 22 | 14 |
| 12 | Northeast | Public | 27 | 19 | 8 |
| 13 | Southeast | Private | 24 | 17 | 7 |
| 14 | Southeast | Private | 22 | 13 | 9 |
| Total | | | 691 | 401 | 290 |

## Research Instrument

The VENCCE (Students' Views on the Nature of Science by way of Contextualization in Ecology, based on the acronym in Portuguese) questionnaire was created with the aim of investigating NOS conceptions among undergraduate biology students (AZEVEDO; SCARPA, 2017b). Its elaboration followed the general procedures proposed by the authors, and involved decisions (Figure 1) regarding: (i) aspects of NOS (the epistemological dimensions) dealt with; (ii) the presence of open or closed questions; (iii) the nature of their items; (iv) the scale and way of evaluating these items; (v) the size and language of the statements; (vi) the expression of authentic situations; and (vii) validation and reliability of their results.

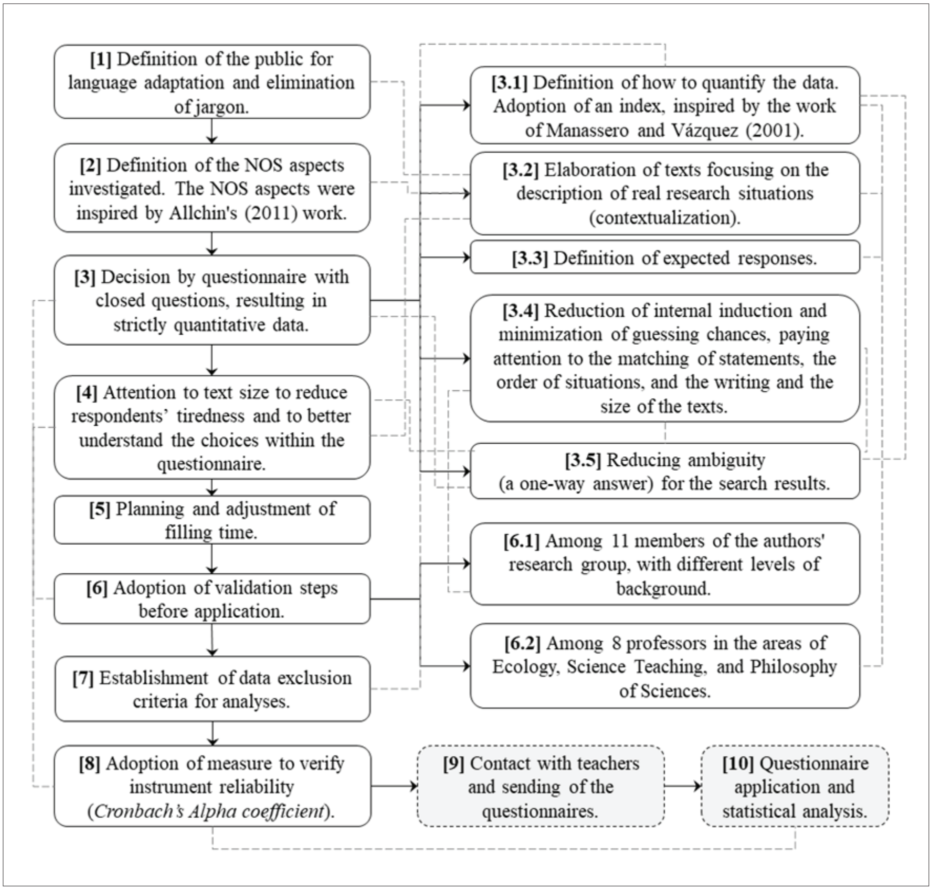


**Figure 1.** Flowchart showing the activities undertaken throughout the study. Stages 1 to 8 refer to instrument planning. Continuous lines indicate the successive steps adopted during the elaboration and application of VENCCE. Dashed lines show correlated actions and decisions, which were continuously weighted throughout the study (adapted from Azevedo & Scarpa, 2017b).

In the questionnaire, there are five situations with Ecology as the theme. The purpose of the questionnaire is to supply authentic situations that could possibly occur in the education and performance of biology professionals. In order for a science view point to be considered well-informed, the emphasis is placed on aspects of NOS that need to be understood by both biologists-in-training and pre-service biology teachers. Prior to creating the instrument, the starting point was the premise that the undergraduates' functional understanding of NOS could be evaluated through the interpretation of scientific situations that describe scientific practices. This is because the interpretation of contextualized situations could reflect a more real level of NOS conceptions, as opposed to students' agreement or disagreement when subjected to decontextualized information. Such reflection arises from recent criticism in the literature regarding the perpetuation of an image idealized by science (ALLCHIN, 2011) and by the tendency to investigate concepts that do not actually explore scientific practices themselves, in detriment of a somewhat philosophic interpretation (IRZIK; NOLA, 2011). Along this line, our preference and efforts to elaborate a contextualized instrument go against the viewpoints considered consensual to the NOS aspects to science teaching, given that the consensual view does not contemplate scientific practices that are devoted to the production of scientific knowledge (ALLCHIN, 2013), neither to specificities of the various sciences (IRZIK; NOLA, 2011). Thus, due to the specificities of Biology, with its scientific value amply discussed in the literature (e.g. MAYR, 2004; ROSENBERG, 2008) (especially when compared to such areas as Physics and Chemistry) and the specificities of Ecology as a science (due to the diversity of methods and the still frequent arguments about the existence of laws as well as the capacity or not for generalization) we believe that Ecology could be an efficient model for exploring NOS conceptions contextually.[5]

As to theoretic dimensions, VENCCE contemplates ten great epistemological themes (Table 2) based on Allchin's (2011) proposal of relevant NOS aspects and on Azevedo and Scarpa's systematic review (2017a). The epistemological themes were divided into more specific sub-themes as, for example, evidence integrity, statistical analysis of data and error, replication and size of the sample, the role of hypotheses in the investigations, the motivation spectrum for undertaking science, ethics in experimentation, communication among scientists, conflicts of personal interest, and forms of credibility. In order to illustrate the nature of some statements according to the epistemological theme and how to exemplify what is called contextualization, brief examples of these are shown in Table 3. Even though the background of the instrument is Ecology, due to its specificities and methodological diversity, application is not extended to defining the scope of Ecology. In VENCCE, and as Ecology is presented as a model for explaining practices associated with the production and validation of scientific knowledge, statements possess a generalist character, as can be seen in the examples presented in Table 3.

**Table 2** – Theoretical composition of the VENCCE questionnaire.

| | *Epistemological theme* | *Number of statements* |
|---|---|---|
| A | Observations and reasoning | 10 |
| B | Methods of investigation | 23 |
| C | History and creativity | 13 |
| D | Human and cultural context | 3 |
| E | Social interactions among scientists | 15 |
| F | Cognitive processes | 6 |
| G | Economy and funding | 5 |
| H | Instrumentation and experimental practices | 4 |
| I | Communication and transmission of knowledge | 11 |
| J | Characteristics of scientific theories | 17 |
| | Total number of statements | 81* |

*Although there are 81 statements, some contemplate more than one theme.

Questionnaire reliability was estimated according to Cronbach's Alpha coefficient (**α**) (CRONBACH, 1951, 2004). The result **α**=0.912 confirmed adequate reliability (KLINE, 2005; WIETHAEUPER *et al*., 2005), thus indicating the VENCCE's capacity for measuring what it proposes (AZEVEDO; SCARPA, 2017b).

Each of the five situations described in the questionnaire is followed by statements (81 in total), together with a scale varying from 1 to 9 for respondents to mark their degree of agreement. A value is assigned to the degree of agreement, according to a scale, producing an index that represents the proximity of the respondents' view to a view that is considered well-informed in light of the presented aspects. The nearer to **+1** the better-informed are the respondent's NOS conceptions, and the nearer to **-1**, the less so. This index was denominated $VENCCE_{index}$ and it is based on an attitude index compiled by Manassero & Vázquez (2001). Statement-ranking taken into consideration when calculating the $VENCCE_{index}$ comprises *well-informed, partially-informed* and *less-informed*. The respondent is expected to mark numbers close to 9 to show the degree to which the statement is reaching *well-informed* and close to 1 for *less-informed*. According to the rank of the statement, the number marked by the respondent is transformed in compliance with an evaluation scale. This is followed by calculating punctuation per class of statement, which, when considered together, result in the $VENCCE_{index}$ (AZEVEDO; SCARPA, 2017b). The calculation of the $VENCCE_{index}$ was carried out with the R environment program, version 3.2.4 (R Core Team, 2014).

**Table 3** – An example of one of the situations contained in the VENCCE questionnaire and its statements, followed by the respective classification of the epistemological theme.

**Situation 5**. *In order to check whether the size of a certain clam would interfere in its chance of being preyed on, a group of scientists took samples. They collected shells from randomly marked-out parcels on a beach, calculated the area of each, and recorded whether they showed any mark that was characteristic of predation.*

| *Code* | *Statement for respondent's appraisal* | *Theme and subtheme used as guides for elaborating the statement* |
|---|---|---|
| S5A | Describe a scientific practice, involving systematic collection. | Observations and reasoning (The role of systematic observation) |
| S5B | Since no experiment was carried out, it cannot be considered a scientific practice. | Methods of investigation (Lack of a unique method) |
| S5C | The conclusion can only be generalized if data collection is repeated in several locations. | Methods of investigation (Replication and sample size) |
| S5D | The conclusion can only be generalized if the collection of data is undertaken with a very large sample. | Methods of investigation (Replication and sample size) |
| S5E | For scientists to reach a conclusion, they should take into consideration the possibility of predation being by chance. | Observations and reasoning (The role of probability in inference) |
| S5F | The results of the study will only be accepted by the scientific community if they are presented in graphic form. | Communication and transmission of knowledge (Nature of the graphs) |
| S5G | The results of the study will be accepted by the scientific community, even when due care was not taken in the collection of data. | Observations and reasoning (Evidence relevance) |
| S5H | The results of the study will be accepted by the scientific community if data receive some statistic treatment. | Methods of investigation (Statistical analysis of data and error) |
| S5I | The choice of statistic treatment could interfere in the final results | Methods of investigation (Statistical analysis of data and error) |
| S5J | Describes a scientific practice, since scientists have formulated a testable hypothesis that has been confronted with the observations. | Methods of investigation (The role of hypothesis in research) |

In order to trace the students' profile, we created personal questions (such as age, gender, parents' formation and type of high school), questions related to the history of course background (semesters taken, course type, contact with meta-scientific themes and participation in scientific initiation) and questions about professional future plans. Only those questions analyzed in the present study are presented here (Table 4).

**Table 4** – Declarative questions used to separate respondents into different profiles, according to research-questions.

| | |
|---|---|
| | ***Questions and options for replies as presented in the instrument*** |
| 1. | How many semesters of the course have you already completed? |
| 2. | Is this your first undergraduate course?<br>[A] Yes<br>[B] No |
| 3. | What type of undergraduate course are you taking?<br>[A] For biologist-in-training<br>[B] For pre-service biology teacher<br>[C] Both |
| 4. | Have you already participated in scientific initiation?<br>[A] Yes<br>[B] No, but I'm interested<br>[C] No, and I'm not interested<br>[D] I don't know what this is |
| 5. | During the course, did you attend disciplines that formally dealt with the themes*:<br>[A] Scientific knowledge<br>[B] Philosophy of Science<br>[C] History of science<br>[D] Scientific Methodology<br>[E] Nature of Science<br>[F] Critical Thinking<br>[G] Scientific Practices |
| 6. | What do you intend to do when you finish your course?<br>[A] Follow an academic career.<br>[B] Follow a technical career in the field of biology. Work, for example, in: consultancy, laboratory analysis, environmental advisory and management, sanitary vigilance, ecotourism, landscaping, parks, museums, research, pest control, bio-restoration, bioethics, etc.<br>[C] Give classes in basic education.<br>[D] Start another undergraduate course.<br>[E] Follow another profession.<br>[F] I don't know yet. |
| | *Each question can be marked with "Yes", "No" or "I don't know". |

## Data Analysis

Use of the $VENCCE_{index}$ is useful because it facilitates both the calculation of a general index that can be applied to all the statements in the questionnaire or just to a clustering of statements. For the $VENCCE_{\text{index}}$ calculation was taking into consideration the valuation in accordance with the statement class (well-informed, partially-informed and less-informed), as well the statements number for each class. Nevertheless, as with VENCCE, students have the option of marking "*I don't know*", introduced to reduce ambiguities; it is not always possible to calculate the $VENCCE_{\text{index}}$ for a group of statements. Thus, every time a student marks the option "*I don't know*", calculation of this index is compromised, since the total number of statements of a certain class (*well-informed*, *partially-informed* or *less-informed*) for that student would be different from that of the remaining students, thereby compromising legitimate comparison. Thus, every time a student marks this option, this answer needs to be excluded from analysis for statement-clustering data.

When choosing the adequate statistical tests, and considering $VENCCE_{\text{index}}$ values of the groups being compared as the variable of interest, the first question was whether data would follow the normal distribution or not. Some authors propose dismissing the normality test when dealing with samples of over 30 individuals (PESTANA; GAGEIRO, 2003). However, even with the large sample for comparison in the present study, data normality was verified with the Shapiro-Wilk test ($p<0.05$), and data distribution was verified through visual analysis (KANJI, 2006). Due to variance non-homogeneity, as well as the presence of outliers, the data analysis alternative was the analysis based on non-parametric statistics. Statistical analysis with the R environmental software version 3.2.4 (R Core Team, 2014) indicated data clustering (MANGIAFICO, 2015). In other words, students from the same university are more alike than those from different ones.

When replying to the first question of the study, NOS conceptions between the various groups of students were contemplated. Comparing the $VENCCE_{\text{index}}$ of all the statements in the instrument, a general index of NOS conceptions, denominated $VENCCE_{\text{index}\boldsymbol{G}}$, was formed. Statistics were then applied to these index values using two main tests ($p<0.05$), the Mann-Whitney-Wilcoxon (U) non-parametric test for the comparison between two groups (KANJI, 2006), and the Kruskal-Wallis (K) test followed by the Dunn *post hoc* test for comparison between more than two groups (MANGIAFICO, 2015).

In order to reply to the second question, the search was directed towards finding differences among the $VENCCE_{\text{index}}$ values of epistemological themes (denominated $VENCCE_{\text{index}\boldsymbol{TE}}$). We checked the differences by ANOVA, followed by the *post hoc* test of Turkey. The difference between the $VENCCE_{\text{index}\boldsymbol{TE}}$ values in according to the undergraduate modality was verified by two-way ANOVA (MANGIAFICO, 2015).

## RESULTS AND DISCUSSION

### Evaluation of factors related to education that could have an influence on NOS conceptions

The use of $VENCCE_{\text{index}}$ for evaluating NOS conceptions of the 691 biology undergraduate students resulted in $\overline{VENCCE}_{\text{index}\boldsymbol{G}}=0.23\pm0.11$. Due to the index scale (that varied from **+1** a **–1**), this average can be considered moderately positive, even though values are still distant from the maximum $VENCCE_{index}$. There was considerable variation between students' $VENCCE_{index\boldsymbol{G}}$ values. Maybe some of the factors investigated could better elucidate the possible causes for this.

In order to answer our first research question, we made four comparisons between different groups of undergraduate biology students. The first one was between $VENCCE_{index\boldsymbol{G}}$ values of students at the beginning of the course (58%) and those at the end (42%). Contrary to our *a priori* hypothesis, the sample showed that NOS conceptions did not vary according to the educational stage (U=73.52 and p=0.07). This result is worrying because it indicates that the NOS conceptions practically do not show changes throughout the course, being little related to the contact with meta-scientific themes addressed in studied academic disciplines or to the amount of time in the undergraduate course.

The second comparison of student $VENCCE_{index\boldsymbol{G}}$ values was between the three groups, viz. biologists-in-training (37%), pre-service biology teachers (26%) and both forms (27%). Analysis indicated that undergraduate course type is a factor that can be associated with students' NOS conception (K=12.47 and p=0.002). Among the three groups, pre-service biology teachers presented the lowest $VENCCE_{index\boldsymbol{G}}$ values (Figure 2). Students attending both courses (pre-service biology teachers + biologists-in-training) presented the highest $VENCCE_{index\boldsymbol{G}}$ values and, therefore, NOS conceptions considered better-informed. This unexpected result, together with data on educational stage, could indicate the need for reviewing the course curriculum's structure, as there are possibly formative elements associated with biologists-in-training that help them in developing better-informed NOS conceptions.

Even though there is a better chance of contact with meta-scientific themes in the pre-service biology teachers' course, due to the prevailing pedagogic subjects that are specific for science teaching, and which possibly deal with questions related to the teaching of NOS as well as the nature of the presiding professors, it is still possible that an idealized vision of science, distant from scientific practices in biosciences, is still common in classroom discussion. An *a posteriori* hypothesis, thus contrived, appears to make sense in view of the recent criticism in the literature (briefly presented in the Introduction) and the orientated construction of the research instrument used here. Although the pre-service teachers' course offers more opportunities for reflection in the classroom and more subjects of an epistemological character, maybe the external aspects and philosophy of science are explored trivially, while the internal aspects related to the production of scientific knowledge are set aside. It is, thus, possible that, on bringing contextualization as a strategy for identifying how well-informed the real conceptions of students are, VENCCE will make meta-scientific themes more accessible for undergraduates, whence the non-conformity of our results with others present in the literature (e.g. JEHNG *et al.*, 1993; LIU; TSAI, 2008; BAYIR *et al.*, 2014) and which oriented the construction of our uncorroborated *a priori* hypothesis.

Generally speaking, pre-service biology teachers' courses in Brazil contain a large number of pedagogic subjects with aims that do not necessarily contemplate working explicitly with aspects related to NOS, but withother, also relevant, themes. The presence of disciplines that explore NOS as one of the aims of science teaching, and work in an explicit and reflexive manner, can be an important factor in raising students' $VENCCE_{index\boldsymbol{G}}$ values.

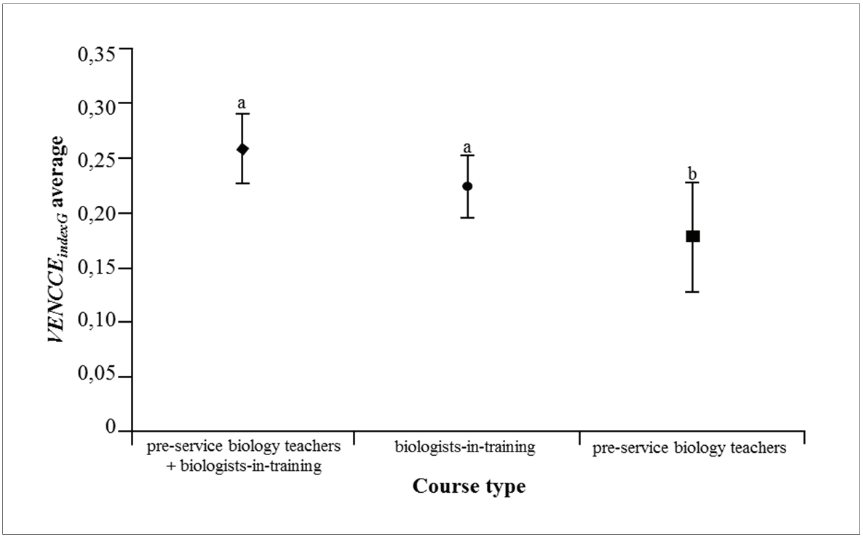


**Figure 2.** $VENCCE_{index\boldsymbol{G}}$ averages according to the course types. Exclusively pre-service biology teachers obtained lower averages when compared to the other two groups. Averages and deviation are shown. Different letters indicate that the averages are significantly different ($p < 0.05$), according to the Dunn *post hoc* test.

The third comparison was between $VENCCE_{index\boldsymbol{G}}$ values of students that declared having had contact with up to three meta-scientific themes in college disciplines (20%) and those who reported having had contact with more than four themes (80%). According to our data, this contact possibly did not interfere in students' NOS conceptions (U=57.89 and p=0.09). This result could indicate that the type of approach, viz., explicit, reflexive and contextualized instead of NOS lists or memorized statements (usually employed when working on themes related to the epistemology of science in the classroom), is more relevant for developing well-informed NOS conceptions. Incidentally, this has already been well-established in the science education literature. So, this perspective of the results is coherent when data related to the educational stage and the course types are analyzed together.

Studies on improvements in the NOS conceptions of a group are usually done by comparing the efficiency of disciplines or explicit intervention (e.g. ABD-EL-KHALICK; LEDERMAN, 2000b; AKERSON *et al.*, 2000; TEIXEIRA *et al.*, 2001; EL-HANI *et al.*, 2004; AKERSON *et al.*, 2006). Some authors have come to identify maturation immediately after such an explicit approach (e.g. LEDERMAN, 1999; AKERSON *et al.,* 2000; ABD-EL-KHALICK; LEDERMAN, 2000a). However, studies focus mainly on evaluating NOS conceptions immediately after an intervention with students. So, studies focused on conceptions after a long interval to verify effective NOS conceptions' change are still scarce. Generally speaking, disciplines that deal with meta-scientific themes occur in the beginning of the course and it is possible that the student has already had contact with these themes in other academic disciplines. As we do not have information about when contact actually occurred with the themes that were included in the questionnaire, a comparative discussion of our results with those of other studies that evaluate the role of intervention and subjects has been restricted.

Regarding subjects, and in an attempt to better understand the differences observed among the course types related to this present research from the point of view of the inclusion of NOS in the curriculum, an initial exploratory research was carried out through notes on the subjects available online and present in the curriculum matrices of the courses on Biology in the 14 universities that participated in the survey. Mentions about NOS were identified in the subjects of only five courses. Even though reference to NOS is an indication of student access to themes, this supposition is circumstantial, since it was impossible to harness respondents to subjects, neither to infer the predominant type of approach (explicit or implicit). This approach, as a factor of the formative elements associated to NOS conceptions, needs to be investigated and discussed in depth in future studies.

The role of SI in NOS conceptions was evaluated in a fourth comparison, carried out between the $VENCCE_{\text{index}\boldsymbol{G}}$ values of students who declared they had participated in an SI (34%) and those who had not (66%). An analysis indicated that there was possibly no influence on the students' NOS conceptions ($U=64.86$ and $p=0.12$). Tavares (2006), when evaluating the role of SI among Brazilian biology pre-service teachers, also found no difference between students who had participated in SI and those who had not. David Moss (2001), while investigating various aspects of NOS among pre-university students for one year, showed that, even among those who were involved in activities related to *doing science*, NOS conceptions remained unaltered throughout the period. With this group of results, it is possible to infer that *doing science* also needs to make sense for the students. Simply following protocols in scientific investigation is maybe insufficient for developing a fundamental critical sense of scientific practice and of the maturation of NOS conceptions. Thus, more detailed investigation on the particularities of those activities related to SI is still necessary.

When analyzed together, the four aspects investigated revealed important characteristics in the education of biology bachelors and biology teachers. Generally, science teaching is based on expositive classes focused on the presentation and memorization of concepts (CARVALHO, 2006; CAPECCHI, 2014). Unfortunately, this is also the case in higher education, in which conceptual education has more weight than the development of professional abilities (WALDROP, 2015). This might explain why NOS conceptions changed very little throughout educational stage or after contact with meta-scientific themes in disciplines. It is to be expected that contact with themes related to the history and philosophy of science, scientific practices and methods, NOS and critical thinking would exert a certain influence on NOS conceptions. This was not revealed in our analyses, maybe because, even if the students have had contact with meta-scientific subjects, this generally occurs in an expositive manner (TALA; VESTERINEN, 2015). In this context, the reflection on NOS ending up not being a focus in undergraduate biology courses.

It is worthwhile to think over about how many subjects the student has experimented with or how often this student has reflected on the nature of doing science while contemplating the various steps of the process of doing science. For example, throughout education, it is rare for students to be exposed to situations in which they are stimulated to develop scientific projects and produce scientific texts, discuss everything afterwards with classmates, and have access to processes of production and validation of scientific knowledge. In subjects of a strictly conceptual nature, only rarely are contents worked out in the light of NOS, thus dissipating the possibility of assimilating the historical, psycho-social, sociological and philosophical characteristics which are intrinsic to the production of knowledge-related-to-a-concept. If the student is only exposed to ready-made concepts, it becomes difficult to fully understand how knowledge is produced.

Gil-Pérez and colleagues (2001) stated that, even though it was expected that in the university environment there would be a more mature understanding of science, due to researchers' scientific education, this rarely occurs. With our data, there is evidence for supposing that, if scientific practice and subsequent reflection on this are not present throughout the subjects comprising a course, it becomes difficult for students to obtain the necessary elements for developing better-informed NOS conceptions and think over their possible performance as teachers or scientists. In this sense, Moss (2001) pointed out that, notwithstanding the importance of an explicit approach to NOS, involving students in the production processes of scientific knowledge and accompanying them through discussion could also be effective in stimulating the development of a mature viewpoint of science.

## Evaluation of the understanding of the various aspects of the nature of science

A comparison between $VENCCE_{\mathrm{index}\boldsymbol{TE}}$ values showed that there are differences in the understanding of the various aspects of NOS (F=235.32 e p=0.01). The epistemological themes H (Instrumentation and experimental practice) and J (Characteristics of scientific theories) were those that presented the lowest $VENCCE_{\mathrm{index}\boldsymbol{TE}}$ values and proved to be the most negatively distant from $\overline{VENCCE}_{\mathrm{index}\boldsymbol{G}}$. The themes *C* (History and creativity) and *D* (Human and cultural context) presented the highest $VENCCE_{\mathrm{index}\boldsymbol{TE}}$ values, besides being the most positively distant from $\overline{VENCCE}_{\mathrm{index}\boldsymbol{G}}$ (Figure 3).

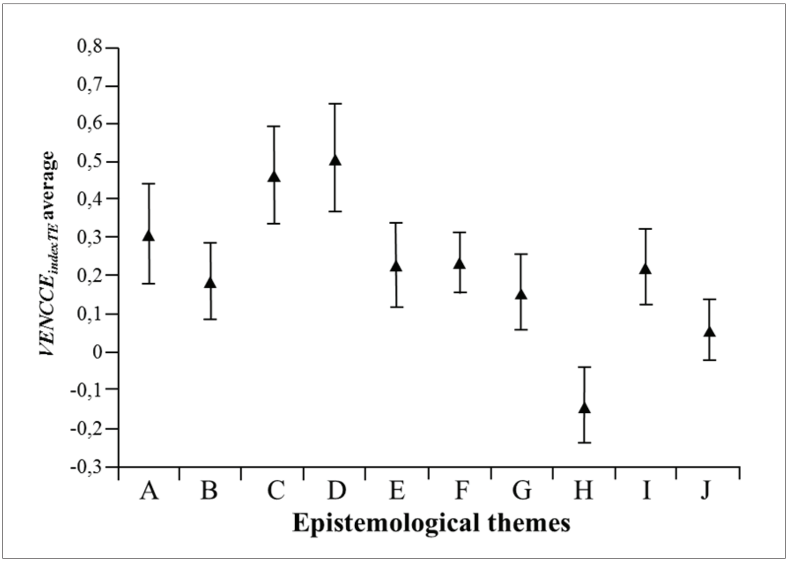


**Figure 3.** $VENCCE_{index\,\boldsymbol{TE}}$ averages of all the students. Averages and deviation are shown. List of epistemological themes: (A) Observations and reasoning; (B) Methods of investigation; (C) History and creativity; (D) Human and cultural context; (E) Social interactions among scientists; (F) Cognitive processes; (G) Economy and funding; (H) Instrumentation and experimental practices; (I) Communication and transmission of knowledge; (J) Characteristics of scientific theories.

The less-informed viewpoint of students about aspects related to instrumentation and experimental practices was a critical point identified in the present study. When students do not recognize experimental practices that are beyond the viewpoint of a unique scientific method for all science (an aspect widely explored by VENCCE), it becomes difficult to recognize their understanding of other NOS aspects, such as those related to the search for evidence or to the use of observation and reasoning.

The VENCCE statements that investigate aspects of scientific practices explore methods that evade the false myth that science is solely experimental. Many statements of the research instrument include recognition of practices, such as sampling and description (relevant for various biosciences, as is the case of Ecology), as being important aspects of well-informed NOS conceptions precisely for placing in evidence the lack of a unique scientific method, as shown in the example statements seen in Table 3. These practices, as well as experimentation, are also based on systematization and the search for evidence, thence questioning the real understanding of students about what it means to state that *science is based on evidence*, a statement present in the various VENCCE contexts. Thus, the negative $VENCCE_{index\,\boldsymbol{TE}}$ values of theme H indicate a less-informed viewpoint of the various scientific methods and, especially, difficulty in interpreting and recognizing scientific practices. A possible explanation for this result is that many students tend to memorize certain NOS aspects, without reflecting on them (ALLCHIN, 2011; SALTER; ATKINS, 2013). Likewise, the absence of reflection on *doing science* is in agreement with other unexpected results, such as the role of SI or contact with meta-scientific themes. This appears to be plausible, especially when considering that most of the students in this study (80%) declared having had contact with various meta-scientific themes in college subjects.

The less-informed viewpoint of respondents, regarding theme *J* (Characteristics of scientific theories), is in agreement with results from studies that report the difficulties students have in defining a theory (e.g. LEDERMAN, 2001; AKERSON *et al.*, 2006; BELL *et al.*, 2011). The theme recurs in questionnaires that investigate NOS conceptions and, in general, accompanies aspects related to scientific laws with the aim of establishing differences between laws and theories. This distinction is not present in VENCCE, since, although being a theme of interest to philosophers of science and even to many researchers in the science teaching area, there is still a certain imprecision on the definition of laws and theories among scientists (WONG; HODSON, 2009). Furthermore, regarding this distinction, it is worthwhile pointing out that a mere distinction between laws and theories, in the context of Biosciences, could be problematic for a NOS viewpoint to be considered well or less-informed. This is especially so because this differentiation could be the result of the mechanical process of mnemonic learning and, thus, meaning less for the student. Due to this preoccupation, those aspects related to laws and theories, and which are present in the VENCCE, seek to investigate conceptions related to the role they play in the organization of knowledge, within the context of scientist activities. The low $VENCCE_{\text{index}\,\boldsymbol{TE}}$ values of theme J could indicate that students have difficulty in recognizing themes as being dependent on creativity and imagination, and that the terms *theory* and *hypothesis* are not alike for science. Many students conceive scientific theories as being irrelevant since they are *only theories,* this having been reported in other studies and at different levels of teaching (e.g. DUVEEN *et al.*, 1993; LEDERMAN, 2001; BELL *et al.*, 2011). In our instrument's context, it is understood that difficulties related to this aspect also reveal resistance in recognizing scientific knowledge as being temporary and that theories are present throughout the various steps of scientific work.

Certain NOS aspects presented no statistical differences between the biologist-in-training, pre-service biologist teacher and the combination of biologist-in-training and pre-service biology teacher, as was the case of themes *A, B, E, H* and *I* (Figure 4). Nonetheless, other themes presented discrepant $VENCCE_{\text{index}\,\boldsymbol{TE}}$ values between forms, the case of themes *C, D, F, G* and *J*, in which the group of pre-service biology teachers presented lower $VENCCE_{\text{index}\,\boldsymbol{TE}}$ values than the other groups. Differentiation in the way of investigating these aspects is called for, since it facilitates evaluating whether the students' viewpoint of NOS is split up, which in fact occurred here.

Although the occurrence of less-informed NOS conceptions among pre-service biology teachers has also been reported in the literature (e.g. LEDERMAN, 1992, 1999; LAKINS; WELLINGTON, 1994; LEDERMAN *et al.*, 2001; JONES; CARTER, 2008; BELL *et al.*, 2011), rarely has the mapping of those NOS aspects denoting deficient understanding been carried out in detail. Indicating these differences is pertinent because it facilitates diagnosis of points of confusion prior to contemplating future feasible alternatives for a punctual and effective solution.

Among pre-service biology students, many of the NOS aspects associated with the $VENCCE_{\text{index}}$ characteristics of a less-informed viewpoint can also be associated to a difficulty in recognizing science as being a human activity (themes *C, D* and *G*). The difficulty in recognizing this characteristic of science also elucidates the difficulty encountered with those aspects related to the production of knowledge (themes *H* and *J*). If the student is unable to recognize that science is a human product, it will be difficult to understand the transitory nature of scientific knowledge (explored in theme J, for example), or its dependence on social, political and economic contexts (themes *D* and *G*). The low $VENCCE_{index\,\boldsymbol{TE}}$ of these themes also reveals the difficulty in recognizing science as a dynamic and collective process.

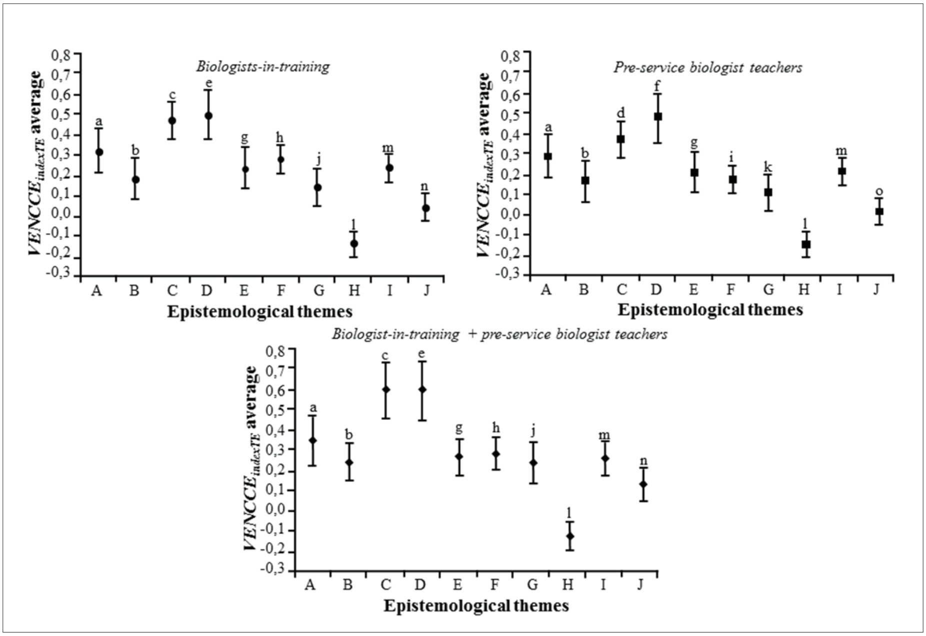


**Figure 4.** $VENCCE_{index\,\boldsymbol{TE}}$ averages according to the course type. Averages and deviations are shown. Note that in the three charts, small letters above the lines do not correspond to the capital letters of the axes. The different small letters indicate that averages are significantly different ($p < 0.05$) (Turkey *post hoc*). The themes *A, B, E, H* and *I* do not present any statistical differences. In the themes *C, D, F, G* and *J,* pre-service biologist teachers presented the lowest $VENCCE_{index\,\boldsymbol{TE}}$. List of themes: (A) Observations and reasoning; (B) Methods of investigation; (C) History and creativity; (D) Human and cultural context; (E) Social interactions among scientists; (F) Cognitive processes; (G) Economy and funding; (H) Instrumentation and experimental practices; (I) Communication and transmission of knowledge; (J) Characteristics of scientific theories.

From the results, it was possible to understand the difficulties most often encountered on working with NOS aspects in basic education, since even among courses where scientific practices are diverse and habitual, there are difficulties in recognizing the social and abstract aspects of science. The observation of higher $VENCCE_{index\,\boldsymbol{TE}}$ values among biologists-in-training, precisely in these features, could indicate that some of the practices presented in the course type can contribute to a less distant viewpoint of certain aspects related to the practice and production of knowledge.

The variation encountered among $VENCCE_{index\,\boldsymbol{TE}}$ values is consistent with the results reported in other studies. According to the aspect investigated, students may present different viewpoints about NOS, somewhat empiric in certain cases (e. g. recognizing the role of evidence in science, but with a positivist view), while recognizing the collaborative nature of science in others (SCHOMMER-AIKINS *et. al.*, 2003; LIU; TSAI, 2008). It has been reported that one and the same student could have a constructivist as well as an empiric viewpoint of science. This could occur when recognizing the tentative nature of science and its collaborative processes (DENG *et al.,* 2011). Thus, it is difficult to state that in every case students possess an exclusively naïve or mature viewpoint.

## Some of the possible implications arising from students' NOS conceptions

The low $VENCCE_{\text{index}\boldsymbol{G}}$ values for the three course groups and the distance from a NOS conception that is considered well-informed is worrying. With the students' answers to the question *What do you intend to do when you finish your course?* (Table 5), it is possible to have an idea of the magnitude of the possible implications of low $VENCCE_{\text{index}\boldsymbol{G}}$ and $VENCCE_{\text{index}\boldsymbol{TE}}$ values on professional performance. Even though an expressive number of students still had no plans for a career (23%), around 62% intended to either take up a scientific or technical career or give classes in basic education. These data reinforce the importance of surveys on NOS conceptions for this public as well as the need to re-consider strategies that could contribute towards the development of better-informed NOS conceptions.

**Table 5** – Students' replies to the question *What do you intend to do when you finish your course?*

| *Option in the questionnaire* | *Percentage of responses* |
|---|---|
| Follow an academic career | 35% |
| Follow a technical career | 27% |
| Give classes in basic education | 10% |
| Start another undergraduate course | 4% |
| Follow another career | 1% |
| I don't know yet | 23% |

When considering that one of the aims of science teaching is to endow individuals with the capacity to make decisions (VANNUCCHI, 1996; SANDOVAL, 2005; PRAIA, 2007), less-informed NOS conceptions among pre-service biology teachers and the consequential lack of workable elements to deal with NOS aspects, can reflect on the practices adopted in the classroom (BRICKHOUSE, 1990; LEDERMAN, 1992; RUBBA; HARKNESS, 1993; KEYS; BRYAN, 2001). The challenge is even greater when considering the absence of didactic materials that specifically deal with NOS aspects in an adequate manner (LEDERMAN, 1992), thereby requiring not only clarity about NOS aspects that the teacher intends to deal with but, mainly, criteria in the choice of didactic material and the adequate planning of classroom activities. However, there is still no consensus in the literature about how much teachers' NOS conceptions can have an influence on those of their students or on their own classroom practices (LEDERMAN, 1999; ABD-EL-KHALICK; LEDERMAN, 2000a; ACEVEDO-DÍAZ, 2008).

## FINAL CONSIDERATIONS

There is a broad debate in the science education literature about the formats of the questionnaires used to assess the students NOS conceptions, this debate contemplates concerns about the nature and scope of questionnaires items and about the type of results that they allow to obtain (e.g. ABD-EL-KHALICK, 2014). Some authors consider that students' NOS conceptions should be sampled through interviews or open questionnaires (e.g. LEDERMAN *et al.*, 2002) in order to reduce problems of interpretation associated with differences between researchers' and respondents' viewpoints. However, data collection based on the application of closed questionnaires, besides requiring less effort on the part of participants to fill in, makes the application to larger samples possible, thereby potentially amplifying statistical power in analyzing and testing hypotheses, due to the greater possibility of generalization (AZEVEDO; SCARPA, 2017a). Furthermore, the use of closed questionnaires, such as VENCCE, besides facilitating the inclusion of a larger number of items, thereby possibly inducing item paring (for example to reduce errors in an analysis), offers more items to be analyzed. Thus, regardless of possible methodological limitations, there is a significant gain in terms of sampling, which represents an initial step towards revealing patterns and supplying indications of where research efforts and improvements of approach in the classroom may still be required. As for the size and geographic distribution of the sample, it was possible to identify where additional assiduity is still required.

The purpose of this research was to present a broader scenario of NOS conceptions among Brazilian biology undergraduates. Although some explanations for this scenario have been presented, future studies dedicated to analyzing the role of one of the various factors analyzed here, through data triangulation, modeling or statistic inference, for example, are still imperative for reaching more axiomatic conclusions. The deeper investigation of other factors that could be associated to the NOS conceptions of this public, as well as the evaluation of approach efficiency to improve these conceptions, are still required in the context of biology teaching in higher education. This proposal gains still greater relevance considering the low indices related to experimental practices, therefore pointing towards an erroneous view of experimentation in the process of producing scientific knowledge, even though the importance of experimental practices in sciences and science teaching is consensual among teachers and students.

Pre-service teacher education is a multifaceted process, arising from the interlocution on different areas of knowledge, such as science, the teaching of science, psychology, sociology, philosophy, history and broader educational questions. Thus, it is possible that many other factors, not analyzed by us, might explain the results exposed here. Even so, considering the viewpoint of science that is predominant among teachers and students, the data as a whole indicate the need for re-evaluating the teaching approach applied in biology undergraduate courses. In the university context, there is a lack of explicit and contextual discussion on aspects related to the production of scientific knowledge, as well as on practices that give priority to the social construction of this knowledge and which are directed at elucidating the influence of society on scientific enterprise involved in the search for ways to produce knowledge and correlate these aspects. An approach that incorporates NOS aspects in an explicit and reflective way throughout the curriculum, and not only in disciplines considered meta-scientific, would contribute towards the maturation of NOS conceptions, thereby achieving a fundamental and ethical position before science, in agreement with a critical scientific training expected for scientists and science teachers alike.

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## NOTES

[1] A more detailed scenario of this theme can be accessed in the systematic review by Azevedo & Scarpa (2017a).

[2] In the literature it is common to use the terms *naïve* and *mature* when referring to individual NOS conceptions. Even though not agreeing with the terminology for possibly comprising a discrimination of value, our option was to keep these terms in some points of the text to keep a terminological fidelity to the cited papers.

[3] When referring to NOS conceptions in the present work, we opted for the terminology *well-informed* and *less-informed*, as against *mature* and *naïve*.

[4] *Plataforma Brasil* is a Brazilian national and unified database of research records involving humans linked to the National System of Research Ethics.

[5] Detailed explanations about the VENCCE instrument, such as epistemological dimensions, implications of the format, validation and analysis, as well as all the situations and statements in full, can be consulted in Azevedo & Scarpa (2017b).

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