

Advantages of studying history and philosophy of science for pre-service physics teachers

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Abstract. The purpose of this exploratory case study was to investigate the views of four undergraduate physics pre-teacher students about the nature of Science (NOS). The students completed an History and Philosophy (HPS) course during the first semester of 2017 at Federal Institute of Education, Science and Technology Sul-rio-grandense (Pelotas – Brazil). Data on their views as well as the maintenance of their views, were collected through two surveys. The first survey was distributed after completion of the course. The second survey was distributed six months later. Students responses demonstrated that undertaking HPS studies was correlated with a positive influence on the development of adequate views of NOS. Students' responses on the follow-up survey demonstrated that positive views on the NOS were retained for six months. The undergraduate physics teacher program from Federal Institute of Education, Science and Technology Sul-rio-grandense, advocates curricular and pedagogical efforts to help science teachers develop deeper understandings of the NOS. Results of this study have important implications for teacher education as well as for the implementation of current Brazilian's education reform.

1. Introduction

In the contemporary world, Science plays an important role in the advancement of many of pressing social problems, including medicine, public health, the environment, and terrorism. A variety of stakeholders use the term “scientifically proven” in different contexts to explore the accuracy and efficiency accredited to Science and its methods. The scientific method is dominant because results in objectively proven findings and it is derived from the facts, rather than being based on personal opinion. This scientific method became known after the Scientific Revolution during 17th century [1].

The advances in the fields of History, Philosophy and Sociology of Science show that the Nature of Science (NOS) is highly distinct from Baconian positivism. Researchers who specialize in the nature of scientific knowledge argue, for example, that scientific ideas are affected by social and historical context [2]. Thomas Kuhn's ideas inspired the shift in the importance of general knowledge of NOS, when previously scientists worked according their values and beliefs. In this case, Science is a human endeavor to understand the nature and operate under subjective biases [3].

Since the 20th century, many researchers and educators have attempted to advance adequate understandings of the NOS. Evidence shows that knowledge of NOS enhance student understanding and learning of science, as also improve the interest in science [2]. Lederman's review of the research [4] on this topic shows that a significant proportion of science teachers do not possess adequate conceptions of NOS. Research demonstrated that science teachers held a positivistic view of Science and many of them believed that scientific knowledge is not tentative. As a result, courses of History and Philosophy

of Science (HPS) were included in several science teacher preparation programs (pre-service and in-service). Studies show that HPS courses promote deeper understanding of NOS knowledge [5–7]. Brazilian research also share these results [8–10].

This work presents results of an exploratory case study that investigated the views, and the retention of views, of undergraduate physics pre-service teachers about the NOS after the accomplishment of an HPS course. We attempted to answer the following research question: *In the context of the survey, how pre-service physics teachers' conceptions about the NOS evolved after the accomplishment of HPS course?*

2. Theoretical Framework

Researchers have defined the constructs of the NOS, over seventy years, in numerous ways. Although there is no precise definition, they have referred to the NOS as: the epistemology of science; science as a way of knowing; and/or the values and assumptions inherent to the development of scientific knowledge [6,11–13].

Despite the lack of consensus about the concept NOS, some characteristics of scientific knowledge are unanimous [2,6,12]:

- Scientific knowledge is provisional;
- Scientific knowledge does not depend entirely on observation and experimental evidence;
- There is no single way to do science (there is no universal step-by-step scientific method);
- Creativity and subjectivity play an important role in the development of scientific knowledge;
- Observations are theory-laden;
- Scientific knowledge is part of social and cultural traditions.

According to Lederman [4], research related to NOS was conducted along the following lines of research (ibid.: 332): (a) Assessment of student conceptions of the NOS; (b) development, use and assessment of curricula designed to improve student conceptions of the nature of science; (c) assessment of, and attempts to improve, teachers' conceptions of the nature of science; and (d) identifications of the relationship among teachers' conceptions, classroom practice, and students' conceptions.

Studies of the first and third areas of research have shown that prior to interventions, students and teachers usually have misconceptions about the NOS [4,12,14–16]. The most pervasive misconception among students and teachers is the notion that a common series of steps is followed by all scientists (1 – *defining the problem*; 2 – *gathering background information*; 3 – *forming hypothesis*; 4 – *making observation*; 5 – *testing the hypothesis*; 6 – *drawing conclusions*). Regarding these misconceptions, the scientific method promotes confirmed knowledge and provides absolute truth and negates the tentative nature of science. Thus, the use of the scientific method by scientists ensures objectivity and avoids error. Misconceptions about experiments, for instance, assume that experimentation is the principal route to scientific knowledge. Students and Science teachers tend to associate Science with experiments, indicating that other ways of gaining scientific knowledge (e.g., speculation) are disregarded. They take no account the role of creativity and imagination in the scientific endeavor.

Researches that focus on the fourth line of research argue that possessing acceptable conceptions of NOS does not imply adequate teaching behaviors related to improving student conceptions. Classroom practice is mediated by a complex set of situational variables (curricular restrictions, administrative policies, classroom management) that affect implementation of NOS knowledge [4,13,17,18]. Despite these results, some authors emphasize that knowledge about the NOS is an important but not sufficient factor [4,18].

3. Methodology

In the present study, Yin's methodological guidelines of case study [19] were applied. The case investigated the influence of the HPS course to development of adequate views of the NOS. The study was conducted with four students enrolled in an undergraduate Physics Teacher Program from the

Federal Institute of Education, Science and Technology Sul-rio-grandense, located in Pelotas, Rio Grande do Sul, Brazil. The HPS course discusses ideas related to positivism and inductivism, and likewise aspects of the NOS.

Two surveys were used as instruments for data collection. Students responded to the first one after the end of the course. The second survey was answered six months later. Responses were compared across three domains: *the role of observation and experimentation in scientific research*; *the tentative nature of scientific theories*; and *the role of error in scientific work*. Data were labeled by Qx_Py, where 'x' corresponds to the first (1) or second (2) questionnaire and 'y' corresponds to the number of the participant (1 to 4). For example, Q1_S2 indicates that this is the answer of participant 2 on the first questionnaire.

4. Analysis and Discussion

Interpretative analysis of students' responses indicated that, in general, they exhibited acceptable views of the NOS, consistent with contemporary conceptions of science endeavor. These results corroborated, to some degree, that HPS promotes adequate understanding for science teachers [5–7,9].

Overall, all participants emphasized that experimentation plays an important role in science knowledge development and the observation is theory-laden. Only P1 expressed the misconception that scientific research only happens with experiments. Table 1 shows all the analysis of all participants' responses.

Table 1. Qualitative analysis of the first aspect.

The role of observation and experimentation in scientific research	
Inadequate Conception (IC)	
<i>Scientific knowledge is obtained by induction from observation and experimentation. Observations are neutral and precede theory.</i>	
Adequate Conception (AC)	
<i>Observations are theory-laden. Observations are influenced by scientists' expectations and beliefs.</i>	
<i>Data analysis</i>	<i>Status</i>
Q1_P1: "Observation and experimentation are fundamental because without them scientific research does not happen."	IC
Q2_P1: "It is through observation that we will have the basis for research."	Unchanged
Q1_P2: "Experimentation is important to show (or try to see) if a given theory, or concept, is correct. Also, experimentation is one of the ways to answer a given problem."	AC
Q2_P2: "The observation must occur regardless the moment it occurs. It is experimentation that helps us to contextualize scientific knowledge, although sometimes it does not."	Enhanced
Q1_P3: "Experimentation is the possibility of reproducing, even if only in an approximate way, an observed or assumed fact."	AC
Q2_P3: "Experimentation enables the perception of details about observed phenomena that with a common sense is not possible to be perceived."	Unchanged
Q1_P4: "Observation has the role of analyzing events through scientist eyes. Experimentation has the role of "testing" to verify the truth of a certain theory."	AC
Q2_P4: "Experimentation is important because can break some paradigms."	Enhanced

Regarding the tentative nature of scientific theories, all participants pointed out that theories can change. According to them, the progress of science is possible because theories can be changed by others, as shown in the table below (Table 2).

Table 2. Qualitative analysis of the second aspect.

Tentative nature of scientific theories	
Inadequate Conception (IC)	
<i>Theories are fixed and unchanging.</i>	
Adequate Conception (AC)	
<i>Theories evolve over time being influenced by the historical, social and cultural context.</i>	
<i>Data analysis</i>	<i>Status</i>
Q1_P1: "Of course they can change, nothing in nature is absolute truth."	A.C.
Q2_P1: "Of course, after all, nothing in the world is tight."	Unchanged
Q1_P2: "Theories can evolve, as long as it is for the growth and improvement of the knowledge or the issue that is being involved."	A.C.
Q2_P2: "Science is always changing, because at any moment a new discovery or a failure in some theory may arise."	Enhanced
Q1_P3: "Although they serve for universal cases, the theories are not exact, so they can be remodeled for their own improvement."	A.C.
Q2_P3: "As I see, science is like the phenomena it studies, it is in constant movement, evolution and expansion. Today what is known as truth, tomorrow may have changed. Thus, the theories that probed this fact will also change."	Enhanced
Q1_P4: "In the course of time many theories do not support themselves, giving rise to new theories."	A.C.
Q2_P4: "Theories evolve because it is part of human evolution."	Enhanced

Positives results were also observed regarding the role of error in scientific work. All participants believed that error is present in scientific endeavours. Scientific research results from individuals who can make mistakes (Table 3).

Table 3. Qualitative analysis of the third aspect.

The role of error in scientific work	
Inadequate Conception (IC)	
<i>Science is absolute and infallible.</i>	
Adequate Conception (AC)	
<i>Science is a human construction, therefore, susceptible to errors.</i>	
<i>Data analysis</i>	<i>Status</i>
Q1_P1: "In my academic experience (undergraduate, specialization, master's and doctorate) I have had proof that the answer is not always the right answer, that errors are also part of the construction of knowledge"	A.C.
Q2_P1: "There is no scientific work without error, after all, the research is basically formed by attempts, mistakes and correctness."	Enhanced
Q1_P2: "I believe that the error is present in the daily life of science, because the scientist will not always get it right."	A.C.
Q2_P2: "Yes, there are several ways, the human being itself, the material used."	Unchanged
Q1_P3: "Yes, since the error will lead us to ask what went wrong or what we will try to answer, correct and improve the method to get as close to the expected or anticipated."	A.C.
Q2_P3: "Yes, because error is the key to transformation, since science is evolutionary."	Enhanced
Q1_P4: "Through error we can see new situations, differences and exceptions. And I do believe that error is present in science."	A.C.
Q2_P4: "Yes, the error proves the opposite of what we think it was."	Unchanged

Although the contributions of a single discipline are limited, as shown by Akerson et al. [12], it was possible to observe, in our context, that the HPS discipline contributed to deeper understandings of NOS. This finding lends empirical support to the efforts advocated on development of teachers' conceptions about the nature of scientific work [4–6,20].

5. Conclusions

Scientific literacy has been focused on international science education reforms, likewise in Brazil. The last Brazilian education reform proposal emphasises the necessity of teaching science as a human enterprise [21,22]. Science teachers are not expected to only teach the science content, but also the historical and social aspects of scientific content. Certainly, effective professional development for teachers has a direct impact on the implementation of reform efforts in Brazilian science classrooms. Helping science teachers develop deeper understandings of NOS is an effort advocated by the undergraduate physics teacher program from the Federal Institute of Education, Science and Technology Sul-rio-grandense, context of this research. Thus, results of this study demonstrate that HPS courses contribute to the development of adequate views of NOS among pre-service physics teachers.

6. References

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