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NOTES and INFORMATION

THE ROLE OF HISTORY AND PHILOSOPHY OF SCIENCE IN TEACHING THE NATURE OF SCIENCE

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ABSTRACT – Currently, the challenges of applying history and philosophy of science (HPS) in science teaching could be attributed to the teacher's unclear view of NOS, lack of skills, and a close-minded attitude towards HPS. There also exists a culture of science teaching which focuses on content memorization and lacks in negotiation. In addition, education document standards and textbooks lack detailed mention of HPS and its role in science teaching.

This paper explores the role of history and philosophy of science (HPS) in promoting a better understanding of the nature of science (NOS) through a systematic literature review. After applying retention criteria, ten (10) articles were selected for review, eight (8) of which covered NOS teaching strategies for students and pre-service teachers while two (2) articles discussed the challenges and obstacles in teaching NOS. Review result reveals that student-centered teaching strategies such as role-playing, replication of historical laboratory apparatus, creative writing, and reflection papers as the most dominant approaches. Short stories on the personal lives of scientists, reading and discussion of historical texts in the form of narratives, and articles or documentaries were also found useful in the application of HPS. Studying and using records of experiments and original works of scientists not only helped improved the teaching of NOS but were also found helpful in clarifying scientific concepts. Investigative analysis of scientific narratives and instrumental approaches in applying documentaries in the history of science, on the other hand, were identified useful for pre-service teachers in understanding the tenets of NOS. Corresponding recommendations as a result of the review were also discussed in the paper.

Keywords: history and philosophy of science, nature of science

INTRODUCTION

Science educators have always searched for and tried ways to develop a lifelong interest in science among students. However, many students are uncomfortable with science and view it as a subject only for the best and the brightest (Jenkins, 2011). For this reason, it is such a reward to see scientific interest even among students who do not envision themselves working as scientists. Still the question of "why can't the students view science as part of their everyday lives and not just a requirement to graduate?" remains.

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The Philippines K-12 Curriculum Guide Science 2016 (DepEd, 2017) dictates the role of science curriculum in promoting scientific literacy among students to help them become better citizens who can apply scientific knowledge in making wise decisions on issues affecting the environment and the society. Osborne (2007) enumerated the four elements of science education towards scientific literacy as conceptual (understanding of the knowledge of science), cognitive (reasoning in a scientific manner), ideas-about-science (understanding the epistemic aspect of science), and social and affective. Of the four, the element of ideas-about-science is usually under-emphasized in science classrooms. In the Philippines, the three learning domains related to the newly implemented K-12 science curriculum; namely: science concept formation, scientific skills acquisition, and developing scientific values were studied in terms of student perception. Montebon (2014) surveyed the student perception on the content, implementation and relevance of the K-12 science curriculum. The study shows that the respondents generally agreed that K-12 science curriculum helped them acquire scientific skills, form concepts, and develop values and ethics. However, the areas recorded with the highest “disagree” and “strongly disagree” responses were for the integration of science in the other subjects and integration of civic, values, and ethics. Hence, these two areas which are important aspects of the nature of science need to be strengthened in the K-12 science curriculum. For scientific knowledge to be “engaging and appealing” to students, there is a need to explore ways to understand not just *what* scientific knowledge is, but more importantly, *how* it is “obtained, checked, and refined” together with the other aspects of the nature of science (Osborne, 2007).

The inclusion of history and philosophy of science (HPS) in science teaching is a rich source for students to understand the nature of science (NOS), its role in the society and its being a human endeavour (Kokkotas & Piliouras, 2008). HPS, as a strategy in teaching science, can develop critical and logical thinking and make science interesting, understandable, and humanized (Yalaki & Cakmakci, 2010). It can also connect science with other disciplines from mathematics to theology, to culture and the arts. This removes the notion of students that science is an “unconnected”, “cleaned-up and pre-justified” product (Monk & Osborne, 1996; Matthews, 1997). As there is no single instructional model or strategy for good teaching, this literature review looked into the attempts made to incorporate HPS in teaching science and its nature.

The promise of HPS and NOS is impeded by how the teachers view NOS and the priority given to students’ knowledge and content acquisition (Monk & Osborne, 1996). More often, teachers’ view of NOS lacks consistency and is inadequate, and their philosophies do not transpire in their teaching practices (Buaraphan, 2010). The forerunner of HPS, Michael Matthews (1997) emphasized that teachers’ professionalism requires a well-grounded historical and philosophical knowledge of the subject they are teaching. Historical and philosophical knowledge serves as a compass that gives direction on what teachers do inside the classroom, gives clarity about how he/she views him/herself as an educator, and the personal and social goals of education (Matthews, 2010).

A teacher’s confidence in teaching the historical contexts of science should be developed during their teacher training. In this light, this paper revisited the current views of science teachers on NOS and the different approaches that were used to deepen their understanding of NOS during their teacher training education.

This paper aims to explore the potential of HPS in teaching NOS both to students and pre-service science teachers using peer reviewed articles and researches. It also examines the challenges of implementing HPS in the classroom. The articles and researches included in this literature review are focused on the teaching strategies used to include HPS in science teaching, the challenges of HPS inclusion in science teaching, and the strategies used to teach NOS to pre-service science teachers. The relevant information gathered in this review could give an overview of the role of HPS in teaching NOS and be of value to science teachers and education researchers.

METHODOLOGY

The literature included in this systematic review were selected from the open sources of ProQuest database. The search was filtered to peer reviewed and full paper articles. The keywords used were *history and philosophy of science in education* which gave 76,668 search results and *history and philosophy of science in science teaching* which gave 52,335 results.

In selecting the articles for review, the following were considered:

i. published in the English language,

ii. the year of publication is not older than 2006, and

iii. full paper available online.

After a thorough reading of the abstracts/full papers, articles which: a) discuss strategies and/or challenges in incorporating history and philosophy of science in teaching (any) science subjects, and b) discuss strategies and/or challenges in incorporating history and philosophy of science in teacher education program were selected for review.

Based on the retention criteria, ten (10) articles were selected; eight (8) of these articles discussed strategies (4 articles) and challenges (2 articles) in incorporating history and philosophy of science in teaching science, and two (2) discussed strategies in incorporating history and philosophy of science in teacher education program. Although the type of research design is not a criterion for retention, all ten (10) articles reviewed were descriptive in nature.

DISCUSSION

Teaching Strategies in Incorporating HPS in Science Teaching

In this literature review, data were collected from a total of nineteen (19) different countries plus other unnamed European countries from the study of Aduriz-Bravo (2014). Of this number, 3 came from America, 2 from Asia, and 1 only from Africa. The integration of HPS in science teaching is very much explored in European countries through the project History and Philosophy in Science Teaching or HIPST (Hottecke & Silva, 2011). The youngest group of students belonged to Grade 5 level while majority of the studies involved were high school students. Different science fields were used as subjects of the study. HPS is also being tried at college levels and on pre-service science teachers training programs. However, in other continents like in Asia, this field of study is new and has caught the attention of several academicians and researches.

This literature review tries to explore the use of HPS in science teaching and how it affects understanding of NOS. The consensus list enumerated by McComas *et al* (1998) was referred to for the nature of science objectives. They describe science as tentative, while being durable, depending on experimental data, observations and skepticism, can be explored using different methods or ways; shows creativity of the scientist, attempts to explain the natural world, theories and laws are different forms of knowledge, influenced by history, culture, society, and technology, scientist must keep record, be open for criticism/reviews by peers and replicability of experiments, and there is open access to new knowledge.

The HPS teaching strategies utilized to promote understanding of the nature of science include role-play (Wielder, 2006; Hottecke, *et al,* 2012), drama and debate (Teixera, *et al,* 2012), use of replica of experiments and calculations (Hottecke, *et al,* 2012; Teixera, *et al,* 2012), historical texts (Coelho, 2009; Dagher, 2014; Teixera, *et al,* 2012), and reflective writing (Hottecke, *et al,* 2012; Teixera, *et al,* 2012).

Role-play humanizes science. It brings to life the conflicts, challenges, and successes of the scientists. The study conducted by Wielder (2006) uses the role-play strategy to portrait the life of Rosalind Franklin, Watson and Crick. During the Franklin, Watson and Crick role-play, the students explicitly modelled and experienced the gender discrimination experienced by Rosalind Franklin, the youthful enthusiasm, passion and arrogance of Watson and Crick, and conflicts among parties vying for the Nobel Prize. A writing-to-learn activity accordingly follows the role-play to allow students to reflect on what they feel about the circumstances the scientists went through. Back in the laboratory, the students were excited to uncover the structure of the DNA using raw data, just like what the scientists do. They were able to understand that science is not just about accepting facts but is a complex process of trials and errors and successes. Role playing aids teachers in portraying science as part of the society and being affected by culture.

Dramas and debates use arguments delivered through speaking activities. Written historical texts put into dramatic forms promoted student's understanding and awareness of their own personal cognitive processes (Teixera, *et al,* 2012). Even the simple storytelling strategy requires teachers to know how to prepare clear and vivid scenes appropriate to the audience. Role-playing and drama are effective and skill-intensive strategies. Role-play and drama production require skills in managing and guiding students as they characterize historical events.

Another engaging HPS teaching strategy is the replication of original experiments and calculations done by scientists. Through this, students design their own experiments and experience how scientists calibrate and stabilize apparatuses. This learning experience touches a number of NOS like reliance on experiments, observation and creativity. In Physics classes, science teachers can try replicating Otto von Guericke's sulfur globes, electric bells, Stephen Gray's electric conduction apparatus, friction machine, or Galileo's inclined plane, to mention a few (Hottecke, 2012).

Another experiment that can be replicated for integrating HPS in the classroom is Kepler's light emission and image formation and various historical electrostatic experiments (Teixeira, *et al,* 2012). The replication of historical experiment and apparatuses as a teaching strategy involves guided inquiry and explicit reflection on NOS and are supported by analysis of historical texts showing how the concept and the experiment itself develops.

Dagher (2014) uses historical texts about Mendel's laws to show the nature of science as a human endeavour. The use of historical texts as an HPS teaching strategy creates interest and helps demystify science, specifically Biology. Dagher's research clearly presents how the recognition of Gregor Mendel as the 'father of genetics' and proponent of the laws of segregation and independent assortment was cleared of questions and controversies by analyzing historical records of Mendel's work.

At the end, his critiques concluded that he is not a fraud, his works are original and valid, and that he articulated the laws of inheritance.

The article also explains how scientific knowledge can be re-characterized (Mendel's principle became Mendel's law) as a result of scientific and cultural factors. Early textbooks are useful in tracing unknown re-interpretation of scientific knowledge that might have taken place overtime. In relation to this, science teachers should venture in comparing new edition textbooks with old edition textbooks. At present, inconsistency in using the terms hypothesis, theory, law and facts is documented in Biology textbooks. Teachers should take this opportune time in class to integrate HPS and NOS in the lesson. If not, this could create debate and confusion among students. Needless to say, teachers should first understand the unique characteristics of Biology as compared with Chemistry and Physics before they can effectively communicate it to their students.

Coelho (2009) clears up the concept of energy by referring to the actual experiments of Robert Mayer and James Joule found in historical texts. The common description of energy found in textbook as being 'indestructible and transformable' leads to a misconception that energy is a thing, something that can be touched. Physics teachers find it difficult to teach the concept of energy by just relying on facts written on textbooks. But as shown in this research, referring to the original experiments and reports of leading scientists in this field greatly helped clarify the meaning of how Robert Mayer and James Joule described energy.

In the context of Mayer's experiment, Mayer did not find any substance. In his report, he used equivalences for heat, position, motion and electricity. In this line, James Joule measured these equivalences. This was reported in textbooks written in the end of the nineteenth century as the "principle of equivalences," different from the "principle of conservation of energy." Although, including the details of these two excerpts in the lesson would entail time, it is still worth doing to avoid/correct misconceptions.

The facilitator model for integrating history of science in teaching proposed by Seker (2011) has four levels: the Interest Level, Sociocultural Level, Epistemological Level, and Conceptual Level. This model offers wide choices of strategies for teachers on how they can incorporate HPS in their science lesson depending on the topic. The Interest Level provides information about the personal lives of the scientists outside their profession. The life events of the scientists humanize science and can catch students' interests on how these events affect their works. The Sociocultural Level looks into the interaction of science, technology and the society, and how the turn of events in human history affects science, and vice versa. This level touches the nature of science as being part of and affected by technology, culture and the society.

The Epistemological Level directly touches the nature of science specifically on the way of doing science; there are different approaches to science: science is evidence-driven and has a tentative character. The Conceptual Level clarifies science contents and knowledge. The approach used by Coelho (2009) could be placed under this level. As shown in Coelho's study, looking back at how the concept was discovered made the concept's meaning clearer. The approach used by Wieder (2006) can also be placed under this level. On the other hand, the students were able to compare their ideas with that of the scientists as found in the study of Wieder,

Recognizing results of several studies that mentioned simply listening and reading texts as having low potential in increasing students' interest, Hottecke *et al* (2012) pays attention to student-centered teaching strategies identified from the HIPST project. Their study revealed that creative writing strategy allows students to reflect on their personal thoughts and relate it to NOS and to a specific historical account. The article cites a letter from Charles du Fay relaying the results of his experiments, and the students' written reply. The strategies highlighted in the reviewed articles were found useful in understanding NOS and also showed how the students' alternative conception is similar or different from the scientists of the past; as a result, motivating students, and developing their reasoning skills and metacognition.

In public high schools in the Philippines where the average class size is forty (40), the use of role playing strategies to introduce HPS can be easily managed by the teacher. The class may opt to do the role playing activity by group or as a class depending on the available time for preparation and presentation. In this technique, the teacher should consider the amount of academic workload the role playing activity entails. To maximize the input of the students in the role playing activity, the teacher may coordinate with other subject teachers to identify possible interdisciplinary projects or activities, e.g., with literature or history subjects.

However, for bigger class size (>40), the use of historical texts and short stories about scientist may be more useful and manageable. The teacher can give a brief introduction of the context of the historical text and provide foundation for the concept being studied. After that, the teacher can divide the class into groups and allow them to analyze further the event following some guide questions. Also, this technique requires minimal student preparation and academic workload. Schedule and lesson planning wise, the integration of HPS through historical texts is more flexible.

The laboratory component of science courses is an integral part of science learning. This is where abstract concepts are concretized and science education is linked to real life. The replication of original experiments and laboratory set-ups may be done during science laboratory period. Resources should not be a problem since some of these original experiments made use of common materials and do not require sophisticated equipment since these original experiments and laboratory set-ups back then were constructed using pre-mature technologies.

Strengthening the understanding of NOS should be a concerted effort of the school administration and the science education department which should take the initiative to provide the science laboratory not just with modern equipment but also with original and historical replicas of experiments. Original laboratory set-ups used by scientists may be constructed and displayed in the science laboratory. This way, the works of the scientists are kept alive such that students may be able to appreciate their works and NOS as well.

Teaching Strategies in Teaching NOS to Pre-Service Science Teachers Using HPS

Teachers should start building strong historical and philosophical foundations of science during their pre-service years. Education institutions offering teacher education courses may consider the use of fictional stories and sample HPS learning units in introducing HPS to pre-service teachers. Science course works during pre-service years affect a teacher's pedagogical beliefs and value system. In the Philippines, pre-service teachers with more science course works in their curriculum have a certain set of beliefs regarding teaching and learning which are more aligned to theories of effective leaning compared to pre-service teachers with less science-related course works (Macugay *et al.,* 2013). This supports the importance of including HPS during pre-service education. The 'Post-Kuhnian Philosophy of Science', a theoretical framework of Aduriz-Bravo (2014) pays more attention to history and society, including language, values, interventions and science practices, and the 'semanticist family' which value model-based approaches to science theories. Further, the 'interventive' nature of scientific activities characterize science as to how we construct the world and not merely by collecting or representing facts from events.

Aduriz-Bravo (2014) justifies the relation of scientific investigation/enquiry with NOS. Thus, elements of puzzle-solving, searching for evidence, scientific reasoning and thinking like that of a detective should be introduced when teaching NOS to pre-service teachers. In this study, the teacher participants were asked to:1) read the story, 2) re-tell the story in class, 3) formulate a hypothesis on the ending of the story and present arguments supporting the hypothesis, 4) reflect on how their background, prior-knowledge and experience influence the structure of the story in no. 2, 5) use the 'mill' artefact in summarizing the scientific and detective investigation approach they did to solve the task, and 6) identify epitomes in science. Later, after performing activities 1 – 6, their answers will lead to the reflection of the NOS perspective of doing science (7).

Pre-service teachers can be presented with an actual sample lesson on how they can apply history of science in teaching science. Howe (2007) developed learning units which are designed for both the pre-service teachers and their future secondary students in Biology. The use of history of science in teaching pre-service teachers promotes understanding of various tenets of NOS. The study of Howe (2007) features the instrumental approach of applying history of science in teaching. The eight (8) lessons developed by the researcher gradually introduced the development of the relation between sickle-cell anemia and heterozygote protection labeled as the "mystery disease" to the pre-service teachers. Moreover, this study is somehow similar to the detective investigation approach introduced by Aduriz-Bravo (2014).

In every unit, the teacher provides additional information like pertinent statistics, results of blood analysis and ethnographic (language and tribes), and environmental (weather and topography) information. This mimics how scientists work in real life. Information based on statistics somehow intrigues the pre-service teachers to learn more about the 'mystery disease' and to arrive at the explanation using the presented statistics. Astonishingly, the explanations provided by the pre-service teachers is similar to the preliminary explanations provided by previous scientists. This approach provides pre-service teachers with valuable experience to successfully understand the various NOS tenets together with the Biology content as: having a common method of knowledge production; being tentative; having subjective component; science as a product of history, culture and society; and not all questions can be answered by science.

Clearly, using HPS is effective in teaching NOS to students and to pre-service teachers. Though there are obstacles and challenges that need to be hurdled, starting the exposure and positive experience with HPS and NOS during the pre-service training of science teachers is a good start.

Challenges and Obstacles in Implementing HPS in Science Teaching

To identify the challenges and obstacles in implementing HPS in science teaching, it is worth revisiting how science teachers view and how they communicate NOS to their students. Karakas (2010) shows from his qualitative analysis which combines series of interviews and class observations that one of the possible challenges in implementing HPS is the teacher's mixed view and understanding of the nature of science. For instance, a teacher may believe that science is objective being based only on numbers, reproducible, empirical, requires creativity, and that theory and law are different. However, that same teacher may also see science as being subjective as the scientist's background reflects in his works, is exact, having only one prescribed scientific method and is influenced by economy and capitalism.

In the study of Karakas (2010), it was noted that the teacher mentioned only one historical account related to the lesson and the life of Isaac Newton and Arrhenius. In one lecture, he discussed the relation of religion with science. In another instance he talked about the impact of Chemistry in the society. Different from the tenets of NOS, in one classroom observation, he taught his class that there is only one way of doing science, and that is the scientific method. Clearly, the teacher participant failed to apply HPS in his class and to gear towards NOS understanding. It is probable that his mixed view of science and not being explicit in aiming for NOS instruction contributed to this event.

Other pertinent observations challenging the implementation of HPS in the classroom are the class size, teaching strategy used by the teacher, and student-teacher interaction. The class size observed in the study of Karakas (2010) was large (200-250 students at the beginning of the semester). On the other hand, the teaching strategy used by the teacher was the traditional, lecture type approach to science teaching. The lecture delivered was mainly on problem solving. There was little to no teacher-student interaction observed inside the classroom. Many students were busy chatting, doodling, playing with cellphones, reading magazines and eating with only a few taking down notes.

The DOST Science Education Institute together with the University of the Philippines (2011) identified similar challenges in science education as unqualified science teachers, large class size, lack of resources and support, and poor-quality textbooks, among others. Truly, class size and the pressure to cover more topics are factors that limit student-teacher interaction and make HPS integration difficult. A teacher may be convinced that HPS can make the class more interesting; however, teachers may opt/decide to prioritize problem-solving as a way of understanding and doing Chemistry. This indicates that the inclusion of HPS in class greatly depends on the intentions of the teacher. To overcome this challenge, smaller class size, more teacher trainings on NOS teaching, and explicit incorporation of HPS in the class are recommended in order to achieve a better science class atmosphere.

Why does embracing HPS into science teaching seems to be very challenging to science teachers? HPS application in class requires drastic change in attitude and beliefs of science teachers. In this case, resistance to change is inevitable. Teachers regard HPS as a complementary strategy to other approaches, not as part of the content to be taught in class. With this in mind, they can easily remove HPS in the scenario. Like the teacher participant in the study of Karakas (2010), the curriculum requires covering much content but limited time prevents teachers to conduct activities not stipulated in the outline even if they want to. Teachers who did not purposely plan to include of HPS in their teaching objectives might just mention it in passing (Karakas, 2010; Hottecke & Silva, 2011). Some teachers also perceive NOS as a non-teachable content. A baseline study participated in by 7 Senior high schools in the Philippines reported that the science curriculum is presented in module form. Sadly, the teachers were not able to finish the topics in the module due to limited time and resources and lack of teacher expertise. In such case, not much learning occurs and the inclusion of HPS becomes difficult.

Results of the HIPST study on the obstacles and challenges in HPS implementation showed that Physics teaching remains traditional and teacher-centered (Hottecke & Silva, 2011). The focus of teaching Physics is on the transmission of truth about nature with little to no error. Scientific facts should, in turn, be memorized by the students. In this setting, students are not expected to draw deeper insights or to negotiate in class. This kind of epistemological belief promotes only low-level skills and ignores the importance of developing reasoning skills and conceptual understanding of students. Also, the opposing beliefs of teachers and goals of HPS is one reason why teachers are hesitant to apply HPS in teaching. Teacher-centered and transmission approach to learning is also true for other science courses (SEI-DOST & UP NISMED, 2011).

Positive attitude towards HPS is not tantamount to understanding it and having the skills to implement it. For instance, the strategies in applying HPS discussed in this review require special skills. Historical accounts in science presents raw, unclear cuts of facts, evidences and concepts. In class, students express their varying opinions and interpretations of HPS. Therefore, teachers are demanded to have good moderating skills so not to get lost with the multiplicity of ideas and answers to be processed in class. Also, the present curriculum lacks details on how to implement HPS in classroom. The role of HPS, for example, is mentioned in the higher goals of science education in the science education standards in Germany and Brazil; however, there is a lack of details on how to apply HPS in different competencies; specifically, it is limited to the role of science in history and the society. As expressed earlier, teachers follow what is written in standard documents and curriculum guides. If HPS activities are not visible in these documents, then teachers tend not to implement. As in the case of Gregor Mendel, textbooks play an important role in science education (Dagher, 2014). It serves as the main source of scientific content for use inside the classroom. However, textbooks nowadays contain ambiguous presentation of the nature of science. Dagher (2014) reported that many books interchange the word hypothesis, inference, theory and principle. Moreover, presentation of science history in textbooks are limited to timelines, dates, and are usually a box for a scientist's biography. Hence, teachers have nothing to look into when they want to apply HPS in the class.

Handling the challenges and obstacles presented above is not straight forward nor easy. Starting with the subject culture in Physics, teachers should be gradually exposed to teacher trainings, module or textbook writing, and other professional development activities. Teachers should also be involved in curricular developments within their unit. Runners of HPS should include specific goals, activities and content where HPS should be applied. Such document serves as blueprints for teachers to follow during their daily science classes. Once written, support systems should be built inside and outside of the school to ensure the success of curricular change as follows:

- Collaboration among teachers,
- Guidance from the school head and support in terms of infrastructure and facility,
- Experts'/Researchers' assistance during the implementation of the curricular change,
- Support from the school administration in approving the curricular changes, and
- Support from other stakeholders like parents.

With the following activities, it is expected that teachers' attitude and epistemological beliefs would become more open for HPS application in teaching science. Researchers can validate teachers' developed learning materials/modules. They can also assist in evaluating the effectiveness of curricular changes in the different facets of student learning like achievement, motivation, and skills and come up with recommendations on how to further improve efficiency. Teachers' experiences may be varied and can be considered as a rich area in implementing HPS for research.

Development of written resources like books intended for HPS application should contain appropriately elaborated historical accounts (not too long and not too short) without compromising the science content where it is being related to, and accurate information on places, dates, names, and terms. Books should also be sensitive of the different situations and contexts faced by teachers in their respective units.

Hottecke & Silva (2011) mention that short term exposure to HPS, like in teacher trainings and workshop, only bring “honeymoon-effects”. Still, experiences during their education courses and pre-service training plays an important role in molding their beliefs about NOS and in realizing the value of HPS in science education.

Sufficient background and experience on the use of HPS is believed to raise the purpose of incorporating HPS in class from just laying down the foundation of science concepts and clarifying theory to deepening of understanding of NOS. The current practice of science teachers in incorporating HPS just revolves around the origin of science theories. Experiments that lead to such theories as well as comparison of present findings on specific science concepts with that of the scientists can lead towards an improved understanding of NOS. At present, NOS is only mentioned briefly in the introduction of science courses and is not reiterated together with the discussion of the other science concepts.

CONCLUSION AND RECOMMENDATIONS

The continuous technological advancements happening in the society should not be a reason for teachers to take for granted the history and philosophy of science and the nature of science. These two aspects are not optional contents that can just be removed in the curriculum whenever the teacher decides. Instead, these two are important contents that should be strengthened not just in the high school level but most importantly in the pre-service education curriculum of future science teachers.

As expounded in this paper, contents of HPS promote better understanding of science concepts; and provide insights on the ideas and epistemic views of the nature of science, the role of science in the society and how science improves the personal life of students. The articles reviewed in this paper affirm HPS as an effective tool in teaching the nature of science. At present, the application of HPS in science teaching is being explored and has been the center of various researches, projects and conferences in many countries.

The quality of science teaching and the student-student and student-teacher interactions in class strongly impact student interest in science (SEI-DOST & UP NISMED, 2011). Teaching strategies that promote the integration of HPS in science teaching and high classroom interactions are student-centered activities like role-play, drama and debate, use of replica of experiments and calculations, historical texts and reflective writing. Further, HPS can be applied to different science disciplines if provided with the appropriate design. The articles discussed in this paper show sample lesson presentations which can serve as pattern or model for teachers who are interested to include HPS in their science teaching.

Despite the promising potential of HPS in promoting better understanding of NOS, and of scientific literacy, its effect has not been felt and seems to be impeded. The obstacle and challenges came from the teacher’s belief that HPS is just an additional strategy and can be omitted from the lesson and their general resistance towards change. In addition, some teachers display poor understanding of the nature of science (Ogunniyi *et al.,* 1995). Also, Filipino students perceived their science classes to have decreased science inquiry activities and students’ use of grades as feedback added to its poor understanding (Bernardo *et a.l,* 2008). These findings could be attributed to problems with teaching practices. The present science curriculum is also loaded with content which teachers need to cover, and leaves no detailed, concrete activities for the application of HPS. Although textbooks should have been a rich source of HPS application, available textbooks only offer HPS as timeline of dates, discoveries, names and biographies presented separately from the content.

The studies recommend the exposure and positive experience of pre-service teachers on HPS during their pre-service training. This greatly influences how the teachers value and understand HPS and NOS since their beliefs and attitudes are being molded during these years of teacher education. If not possible during their pre-service education, conducting teacher trainings on HPS and NOS teaching methods is recommended. Engaging experts in HPS and NOS to work together in the curriculum review and module/textbook development aimed at producing/creating specific activities and lesson plans for teachers to use in their classes is likewise recommended.

Science education agencies in the country like the Science Education Institute-DOST and the University of the Philippines National Institute for Science and Mathematics Education have put their best effort to identify, describe and offer solutions to the challenges faced by science teachers and students. Just like any education agenda, small gradual steps should be taken to hurdle the challenges identified earlier. This should start with the teacher who is the key to the implementation of change in the classroom.

STATEMENT OF AUTHORSHIP

The author conceptualized the research problem, identified thematic points, did the literature search, contextualized findings and undertook the writing of the manuscript.

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