# Significance of History and Philosophy of Science in Instruction: A Phenomenographic Inquiry

**Lea F. Dollete**
leadollete2@gmail.com
Faculty, College of Teacher Education
President Ramon Magsaysay State University – Botolan

***Abstract*** This phenomenographic study explores the conceptual understanding of science teachers on the significance of History and Philosophy of Science (HPS) in science instruction. A total of 15 teachers were purposively selected in government-owned schools in Zambales, Philippines. The study utilized one-on-one interview sessions with the participants using a structured interview guide. Thematic analysis served as the springboard for the identification of categories and underlying themes, which facilitated the construction of outcome spaces. The study revealed that the Filipino science teachers saw and understood the significance of HPS in science education in four different ways: 1) HPS humanizes science education; 2) HPS improves scientific literacy; 3) HPS enhances teachers' pedagogy; and 4) HPS boosts 21st century skills. Implications for science education framework in the Philippines as well as to HPS curriculum enhancement were further established in the study.

***Keywords:*** *history and philosophy of science, phenomenography, science education, scientific literacy, significance of HPS*

Dollete, L. F. (2021). Significance of history and philosophy of science in instruction: A phenomenographic inquiry. *The Normal Lights*, *15*(1), 51 – 75.
Corresponding Author: leadollete2@gmail.com

## Introduction

Science education is a crucial element in our knowledge-based society. As emphasized by Hendriks and Kienhues (2019), science is no longer just a hypothetical and secluded approach to analyzing the socio-natural world, but now affects people's everyday living in a multitude of ways. In consonance with the global vision for science education, students of today must enhance their scientific literacy and learn to use it to rationalize, solve problems, and make decisions about pressing global challenges (Forbes, Neumann, & Schiepe, 2020).

In the Philippines, the current state of science education, particularly in the basic education level, lags behind other countries in the world based on the results of the 2018 Program for International Student Assessment (PISA) which was released by the Organization for Economic Cooperation and Development (OECD, 2019). Results showed that among 79 participating countries, the Philippines ranked last in reading and second to the last in both mathematics and science. Such poor standing of science students calls for more innovative and engaging strategies in science to improve the students' scientific literacy. One element of science instruction which may improve scientific literacy is to make science more fascinating to the learners, which may be derived through the use of history and philosophy of science (HPS) as a teaching strategy.

History and philosophy are imperative elements that could make science education thought-provoking to students and fascinating among science educators (Rogayan, 2015). He also pointed out that the role of HPS is undoubtedly substantial as it serves as a verge towards overcoming the so-called 'sea of meaningless.' In fact, it has been a challenge for educators to achieve a full understanding of scientific subject matter if they will not be able to incorporate history and philosophy in the realms of science education.

Globally, several studies have been conducted on the role of HPS in instruction. Studies have focused on HPS and its contributions in chemistry education (Sanchez, 2016), its role in physics education (Henke & Hottecke, 2015; Hottecke, Henke & Riess, 2012), HPS in exposing bad science (Shahvisi, 2015), the value of philosophy of science for history of science (Arabatzis, 2017), the challenges of HPS implementation in instruction (Hottecke & Silva, 2011), and its contribution to science for citizenship (Stefanidou, 2019).

In the Philippines, a dearth of literature has been published regarding HPS, specifically its importance in teaching the sciences. Macale (2019) focused on the role of HPS in teaching the nature of science. Teachers' role is quintessential in appreciating the students' challenges, weaknesses, and difficulties in science learning. This can be done if teachers have adequate knowledge on the rich history of the development of science. Thus, knowledge on HPS can be an essential element in curriculum development and the delivery of lessons (Matthews, 1994).

Since limited studies have been done in exploring teachers' conceptions on the significance of HPS in science instruction, specifically in the Philippines, the present study attempted to explore how teachers of science conceive the importance of HPS in teaching science.

## HPS in Science Instruction

Integrating HPS in science instruction has been very challenging for teachers. Macale (2019) cited that the challenge of teachers on HPS integration in science teaching could be attributed to the educator's unclear view of the nature of science (NOS), lack of skills, and a close-minded attitude towards HPS. Educators "need to make science education effective and relevant for a large and necessarily more diverse fraction of the population" (Wieman, 2007, p. 3)." To do so, he suggested that educators need to transform how learners perceive things so that they will be able to utilize science and its concepts like how scientists do. He averred further that this is possible if teachers approach science instruction like a science. Thus, science teachers need to introduce to students the rich methodological dimensions of science. In other words, educators need to make science education relevant, engaging and meaningful for the students. The need to inculcate how science will be valuable and significant in the students' daily lives must be given emphasis. Furthermore, science teachers should take advantage of the students' valuable questions (Matthews, 1994). Questions like the reasons why students need to study science, the manner by how students verify whether the information is factual or not, and if a certain piece of information makes sense at all, are essential for teachers to discuss to further enhance students' curiosity, inquisitiveness, and critical and creative thinking. These questions will broaden the scientific-mindedness of the students, which can influence their perspective on a myriad of issues and concerns in the environment where they belong.

Teachers could employ several strategies in integrating HPS in science lessons. 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 helpful in the application of HPS (Macale, 2019). Additionally, Yalaki and Cakmakci (2010) pointed out that HPS, as a strategy in science instruction, can enhance the students' critical and creative thinking and make science exciting, comprehensible, and humanized.

## Perception of Teachers on HPS

The inclusion of the HPS in science instruction is extensively acknowledged; however, the actual implementation in learning institutions is still lacking (Henke & Hottecke, 2015). They averred that teachers' "perceived demands point out critical aspects of pedagogical content knowledge necessary for confident, comfortable and effective teaching of HPS-based science" (p. 39). Additionally, Matthews (1994) affirms that the inclusion of HPS in the curriculum may not answer all issues surrounding science education, but it will definitely contribute to make the general task of enhancing science teaching-learning process to adapt to the changing world and demands of the industry. The demands that educators perceive when planning and integrating HPS in science are expected to be critical for the arbitration of educators' decisions for or against HPS (Hottecke et al., 2012).

Hence, this study was conducted to explore the conception of science teachers on the phenomenon of the significance of HPS in teaching science.

## Framework of the Study

The study is anchored on the concepts put forth by Matthews (1994) on history and philosophy of science (HPS) and teaching. He expounds the impact of teachers' pedagogical knowledge on HPS towards improving the scientific instruction as well as science education. As he puts it, "the rapprochement between HPS and science education is not only dependent upon the virtues of a liberal view of science education; a good technical science education also requires some integration of history and philosophy into the program (p. 8)." Henceforth, the knowledge of science entails understanding not only the products of science – scientific facts, theories and laws – but also the processes of this systematic enterprise.

The inclusion of HPS in the curriculum is likewise magnified by Matthews (1994). He asserts that the HPS has indispensable functions in a multitude of theoretical concerns that pedagogues of science and science teacher educators need to deal with. Such issues include questions like, what really comprises a quintessential science curriculum for all students. In traditional cultures, how science should be taught? What are the effective ways of advancing scientific literacy? Lastly, how do we address conflict which can transpire between science curriculum and deep-seated religious or cultural values and knowledge? All of these issues are part and parcel of the vital part of HPS in education.

Moreover, Matthews (2014) mentioned that the belief that the learning of science needs to be complemented by learning about science is basic to liberal approaches to science instruction. Additionally, he argued that if science is taught merely as a technical course devoid of its cultural and philosophical magnitudes, then the positive results of science education are less able to fructify in society. Kampourakis (2015) also averred that teaching science makes more sense in the light of HPS. He added that it is vital to augment the "conceptual sophistication of science education as much as possible, and the contributions of HPS scholarship" are critical for a better understanding of the ideas and processes of science (p. 808). Hence, the present study used Matthew's arguments as a framework in understanding the teachers' conceptions of the phenomenon being investigated.

## Purpose of the Research

The study was conducted to qualitatively explore the conception and perspective of science public school teachers on the significance of history and philosophy of science (HPS) in science education, specifically in science instruction. This will serve as baseline research for further exploration of the connection of HPS and science education in the Philippine context.

## Methodology

### Research Design

The study used phenomenographic research design to qualitatively explore the perspective and understanding of the science teachers on the importance of HPS. This line of inquiry explores differences in the experience and perception of some aspects of the world (Bruce et al. as cited in Abulon & Balagtas, 2016). In this research approach, the researcher aims to "categorize the subjects' descriptions, and these categories in turn form the basis of phenomenographic research" (Stolz, 2020. p. 1081).

### Participants

The study purposively involved 15 science classroom teachers, comprised of 10 females and 5 males, from government-owned secondary schools in the Division of Zambales, Philippines. The selection criteria are: (a) regular public school teacher; (b) teaching science subject in the junior high school; and (3) in the service for at least three years.

### Instrument

The researcher utilized a self-developed structured interview guide to determine how science teachers understand the significance of HPS in science instruction. The interview guide was content validated by three experts in science education and philosophy. The tool asked the key question: Why is HPS important in science teaching? The question allowed flexibility to investigate further the responses given by the participants for elucidation purposes (Abulon & Balagtas, 2016).

## Study Context

The study involved participants from eight government-owned secondary schools in the Division of Zambales. The schools are regulated by the Department of Education and are offering junior high school program. Schools were chosen for the reason of convenience, specifically the schools' accessibility. Only science teachers of these schools were chosen as participants in this research.

## Data Collection

After securing permission from the concerned offices, the researcher secured informed consent to all the 15 classroom teachers. The researcher likewise asked the participants to audio-record the interview. After which, the individual interview was conducted in the place identified by the researcher and the interviewees. The study was conducted from June to December 2018 before the COVID-19 pandemic.

The interviewer first introduced herself to the teacher-participants and explained the objective of the study. The interviewer made an informal conversation with the participants before the formal interview to establish rapport. The interview (that utilized structured interview guide to elicit responses from the teacher) lasted for 10 to 20 minutes per participant. After the interview, the researcher transcribed the recordings. Since the responses of the teachers were in English, no translation has been made. The transcripts were shown to the participants for member checking via electronic correspondence to increase the validity of the results.

## Data Analysis Framework

The following steps (Figure 1) in analyzing the data were undertaken as adapted from the study of Sjostrom and Dahlgren as cited in Khan (2014).

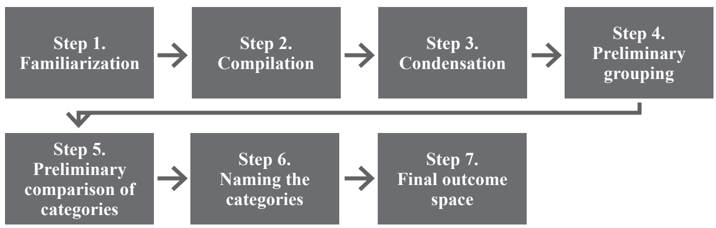


*Figure 1.* Data Analysis Flowchart.

The familiarization step involved the reading of transcripts several times to better grasp the transcriptions. The compilation step required a more detailed reading to infer similarities and differences of the content. The next process was the condensation step which involved the selection of extracts relevant to the study. This step sifted through and omitted the irrelevant and redundant components from the transcripts. Afterward, preliminary grouping was done which focused on categorization of similar responses into initial groups. The next stage was the preliminary comparison of categories. This involved polishing of the preliminary listing of categories to compare against the pre-listed groupings. The naming of categories came next where categories were named to emphasize their essence based on the attributes and distinguishing features of the group and to differentiate them from the other. The final outcome space was crystallized towards the end. In this step, the researcher identified the final outcome space based on the central connections and how the respondents differently understand the particular phenomena.

The researcher also provided the participant's code number for each response, including sex, and science teacher

(ST) participant number (i.e., Male, ST2). The outcomes space of the study were the surfaced categories and emergent themes on how the science teachers critically conceive the significance of HPS in science instruction. The crystallized outcome space described the relationships between categories.

## Findings

This section of the study presents how science teachers conceive and understand the significance of HPS in science instruction. Outcome space was crystallized based on the teachers' conceptions since the present study is a phenomenographic inquiry. The science teachers reveal varying points of view on how they conceive the importance of HPS in science teaching. A text table was prepared to summarize the categories and emerging themes that surfaced in the study (Table 1).

Table 1.

*Conceptions of Science Teachers of the Significance of HPS in Science Instruction*

| Significant Indicators | Categories | Themes | Description of Themes |
|---|---|---|---|
| One importance of HPS is that it makes science classes more interactive, challenging and fun. Students are challenged to think, argue and ask more questions." [Female, ST4] | HPS humanizes science education | Makes science classes more challenging | HPS makes science students to think more. |
| HPS helps me to better understand what I teach to my students. And it also helps me to improve the way I teach and the 'why' I teach. [Female, ST3] | | Contributes to the fuller understanding of the subject matter | HPS provides students' holistic understanding. |

| | | | |
|---|---|---|---|
| Basically, HPS can enhance my students' way of argumentation and thinking. They become so inquisitive and more curious on different scientific things. [Female, ST5] | HPS improves scientific literacy | Enhances students' reasoning and critical thinking skills | HPS facilitates development of critical-minded learners. |
| History and philosophy of science provides educators true understanding of Science. It provides genuine and valid information that facilitates better Science instruction. [Female, ST1] | | Provides teachers' authentic understanding of science | HPS provides better understanding of scientific concepts. |
| Through HPS, I am able to appreciate the learning difficulties of my students and do something about it. My interventions in the classroom would always be based on the dilemmas being confronted by my students. [Male, ST14] | HPS enhances teachers' pedagogy | Assists teachers appreciate the learning difficulties of students | HPS makes teachers appreciate the learning needs of students. |
| HPS develops my teaching approaches. [Male, ST11] | | Develops teachers' teaching methodologies | HPS improves teachers' way of teaching. |
| As we live the 21st century society, HPS helps a lot in terms of developing students' life and career skills as they are immersed mainly on understanding scientific facts and information relevant to their lives. [Male, ST15] | HPS boosts 21st century skills | Increases students' life and career skills | HPS enhance students' global skills. |
| HPS improves teachers' communication skills specifically in communicating scientific ideas and principles in a way that students could understand easier. [Female, ST2] | | Enhances teachers' communication and collaboration | HPS teachers' scientific communication. |

## HPS humanizes Science Education

The first theme under category 1 is that HPS makes science classes more challenging. Teachers conceive the importance of HPS in science education as a tool that makes science classes challenging, interactive and fun. HPS also challenge students to think more. One participant shared, "*one importance of HPS is that it makes science classes more interactive, challenging and fun. Students are challenged to think, argue and ask more questions"* (Female, ST4). This is seconded by another male participant who mentioned that "*with the integration of HPS in science teaching, students are challenged to be more inquisitive about a lot of things related to Science"* (ST12).

The second theme focuses on the contribution of HPS to the holistic understanding of the subject matter. A female teacher mentioned that "*HPS helps her to better understand what she teaches to her students*". She added that "*HPS also helps her to improve the way she teaches and make her reflect her 'why' in teachin*g" (ST3). The sampled science teachers see HPS as a tool that facilitates a better understanding of the subject content. One teacher said, "*HPS contributes to holistic understanding of Science. The content of the subject is easily taught when incorporated with HPS principles*" (Female, ST7).

## HPS improves Scientific Literacy

The second category focuses on how HPS improves the scientific literacy of the teachers and students. The first theme culled under this category is the conception of HPS as a tool that can enhance students' reasoning and critical thinking skills. A female teacher stressed that HPS can enhance her students' way of argumentation and thinking. She mentioned that *her students become so inquisitive and more curious about different scientific things* (ST5). Another participant shared the same perspective "*that HPS enhances students' argumentative, reasoning, rational thinking and critical thinking skills"* (Female, ST4). "*Students also keep on asking questions, rational questions"* as stated by another teacher (Male, ST12). Relatedly, one teacher (Female, ST9) shared that HPS "*also improves the literacy of students in Science."*

The second theme under category 2 focuses on how HPS can provide teachers' genuine understanding of science. One participant (Female, ST1) said that HPS provides educators true understanding of science. She also added that it provides genuine and valid information that facilitates better science instruction. Another teacher said, "*I myself get to have a deeper understanding of Science since I integrate HPS in my Science classes*" (Male, ST13), which reflects how HPS can give an in-depth understanding of science on the part of the teachers. "*HPS helps me and my students understand better the nature of Science"*, said by another participant (Female, ST8).

## HPS enhances Teachers' Pedagogy

History and philosophy of science (HPS) as a tool in enhancing teachers' pedagogy was likewise conceived by the participants as one significance of HPS in science instruction (category 3). The first theme that surfaced under this category is concentrated on the role of HPS in assisting teachers appreciate and respond to the learning difficulties of students. *"Through HPS, I am able to appreciate the learning difficulties of my students and do something about it. My interventions in the classroom would always be based on the dilemmas being confronted by my students,*" shared by one teacher (Male, ST14). With HPS as a teaching strategy, teacher is able to recognize the strengths and weakness of their students in their lessons. One teacher also reiterated that HPS *"can be helpful in understanding the problems encountered by students in Science classes (*Male, ST11).

The next theme under this category delved on the importance of HPS in developing teachers' teaching methodologies. One response under this theme is that *"HPS develops my teaching approaches"* (Male, ST11). Relatedly, another participant said that *"HPS is important tool in enhancing teachers' pedagogical approaches in Science"* (Female, ST9). ST9's and ST11's responses show that HPS is not just a simple teaching strategy but can be considered as a tool that can improve teachers' pedagogical knowledge.

## HPS boosts 21st-century Skills

HPS as a tool in boosting the 21st-century skills of both the teachers and students represents the last category identified by the science teachers. HPS as an important element in increasing students' life and career skills is the first theme culled under the fourth category. One teacher shared, *"as we live the 21st century society, HPS helps a lot in terms of developing students' life and career skills as they are immersed mainly on understanding scientific facts and information relevant to their lives"* (Male, ST15). This sharing mirrors the potential of HPS in expanding the global and future skills that students must possess. In the same vein, a female teacher shares the same view that "*HPS helps students improve their life and career skills"* (ST10).

HPS as a tool for enhancing teachers' communication and collaboration is the second theme generated in category 4. *"HPS improves teachers' communication skills specifically in communicating scientific ideas and principles in a way that students could understand easier"* mentioned by one female participant (ST2). Another female participant seconded this that HPS improves teachers' collaboration in terms of improving the teaching-learning process (Female, ST6).

The study shows several significant findings relevant to various ways in which the science teachers 'conceived' the significance of HPS in science teaching. Abstractions done on the aforementioned theme consequently resulted to the outcome space that represents the teachers' concept of the importance of HPS in science education (Figure 2). This outcome space succinctly summarizes the emergent themes culled out under each conceptual category.

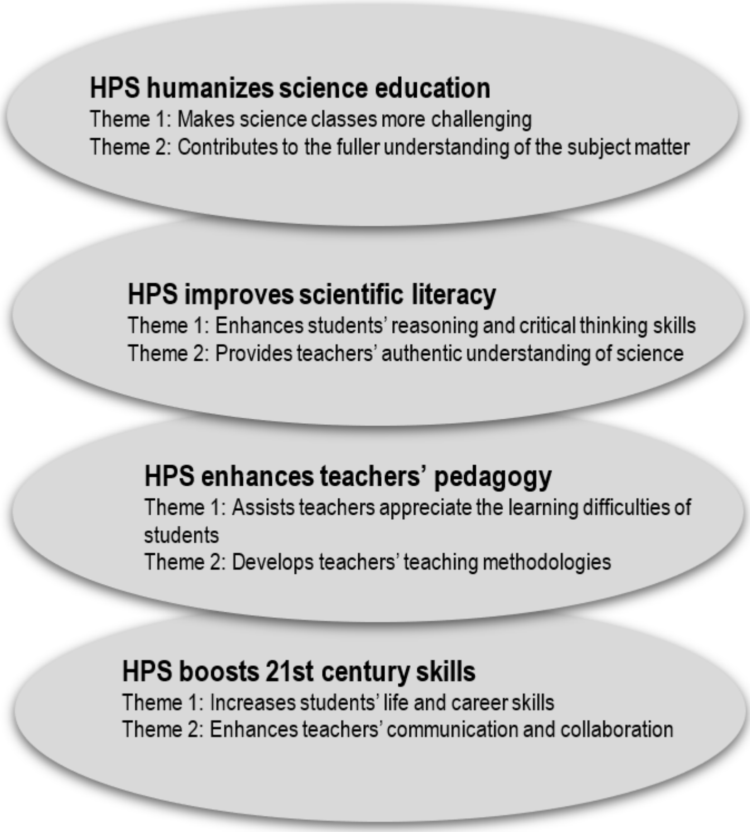


*Figure 2.* Conceptual Framework of the Outcome Space.

## Discussion

The study described the science teachers' conceptions on the significance of history and philosophy of science (HPS) in instruction. HPS is considered to be an indispensable tool in science education. This qualitative study illustrates four major categories of the importance of HPS in science teaching – HPS humanizes science education, improves scientific literacy, enhances teachers' pedagogy and boosts 21$^{st}$-century skills.

The first circle of the outcome space shows that HPS humanizes science education. This implies that HPS makes science classes more challenging and contributes to the holistic perception of the subject content. HPS, as a strategy in teaching, can help students better understand the humanistic and cultural aspects of science (Matthews, 2018). Through HPS-integrated approaches like role-playing, students will see how scientists' lives and works can humanize science and contribute to their wider perspective as human beings (Macale, 2019). HPS can also fascinates students with the challenging and relevant activities integrated in the process. The inclusion of HPS dimensions in curriculum and learning hubs can humanize the sciences and make them more associated with personal, moral, socio-cultural, and political issues (Matthews, 2009). Additionally, Mathew confirms that HPS can provide broader understanding of science content and can further help hurdle the sea of meaninglessness. With HPS, contents and concepts in science lessons can be humanized, thus reducing too much formalism that makes science more abstract to the students.

The educators' perspectives on the role of HPS in improving scientific literacy are mirrored in the second circle of the outcome space. This implies that HPS can help in enhancing students' reasoning and critical thinking skills, and in providing teachers' authentic understanding of science. As a teaching tool, HPS can be an effective method in fostering scientific literacy or the understanding and awareness of the scientific concepts, principles, laws and theories. It is also emphasized by Coelho (2013) that it is generally accepted that HPS is valuable in analyzing science concepts, theories and even some experiments. Learning about HPS is not a waste of time as students have to make as many fruitful experiences as possible with the inspiring nature of history and philosophy of science for the development of their critical thinking and better learning (Hottecke et al., 2012). With the global challenges that continue to confront the society like the new industrial era, disruptive technologies and now the global pandemic, it is imperative that teachers should employ HPS in science classes. Integrating HPS in science classes will develop a generation of critical and creative thinkers and scientifically literate individuals who can help people or the public understand scientific concepts and ideas. Matthews (2017) asserted that HPS could "enliven teaching and enlarge intellectual horizons when it is used to illuminate any topic in the curriculum" (p. 178). In this way, teachers can craft lessons and learning tasks which are relevant and contextualized for the students to appreciate and utilize in their daily living.

The third circle is focused on the importance of HPS in enhancing teachers' pedagogy in terms of assisting educators to appreciate the learning weaknesses of the students and developing teachers' instructional methodologies. This concept of HPS integration reflects how HPS can help the teachers enhance how they teach science concepts and how they plan their lessons based on the diverse students they have, which may also help them guard against misconceptions and alternative conceptions that students may acquire. Teachers view HPS as a tool to improve their pedagogy. It can probably improve heutagogy or the self-determined learning of students in this era of flexible learning modality and Education 4.0 where digital technologies in learning are harnessed and maximized. Such implication of this study supports the findings of Hottecke and Silva (2011) that teachers are the gatekeepers of their respective learning hubs and instructional innovations. Thus, their perspectives and potentials encumber or permit and shape the process of learning. The manner by which a teacher can fully impart knowledge must start by accepting the weaknesses, difficulties and challenges of his/her mentees. Likewise, it also important to note that HPS can be a lever to teach various concepts in science. Teachers just need to build a relevant HPS-based teaching strategy considering scholarly literature and students' baseline competencies. Furthermore, Matthews (1994) stated that by historical studies educators may fully understand some of the conceptual difficulties transpired in the earlier development of the scientific disciplines. In this way, the knowledge can help resolve such dilemmas. Matthews (2018) even stressed that teachers acknowledge that they have a lot to share to science education in two aspects: understanding concepts and understanding the nature of science. Interest and capacity in integrating HPS must then be encouraged in teacher education and graduate education courses (Matthews, 2018). HPS does not merely "supply a cultural extra to the study of the scientific knowledge; it appears as a reservoir of potentially fruitful tools for teaching and learning this knowledge" (Bachtold & Munier, 2019, p. 30).

The final circle of the outcome space shows the teachers' final conception characterized as the role of HPS in boosting 21$^{st}$ century skills. It includes the concept of increasing students' life and career skills and enhancing teachers' communication and collaboration. With the changing landscapes of education brought about by globalization and the emergence of the future job skills as well as the onset of the fourth industrial revolution (FIRe), both students and teachers must possess the 21st century skills needed to keep abreast with the demands of the society and the emerging needs of the new industrial era. Furthermore, the current COVID-19 pandemic demands adaptive skills for the people to thrive and survive this era of disruption. Rogayan (2018) emphasized that the nature of teaching is rooted primarily in curing ignorance, broadening one's perspective and enhancing individuals' potentialities. Teachers then can utilize HPS as an element in harnessing their 21st century skills and that of their students. Henke and Hottecke (2015) stated that HPS is a suitable pedagogical strategy for advancing a deeper knowledge of science content, enhancing higher-order thinking skills, and obtaining a sufficient understanding of the nature of science needed in today's society.

These skills are also needed in order to surmount the challenges of the $VUCAD^2$ world – a world which is volatile, uncertain, complex, ambiguous, diverse and disruptive. Morales (2020) reiterated that $VUCAD^2$ realities "traverse the domains of education exhibiting wider perspective of the changing environmental challenges" (p. viii). Thus, it is a challenge for teachers to reframe and rethink their pedagogy by utilizing HPS as a tool in science instruction for the students to thrive well in the $VUCAD^2$ world.

## Conclusions and Implications

The present study qualitatively described the conceptions, understanding and perspective of science public school teachers on the importance of History and Philosophy of Science (HPS) in science instruction. The science teachers conceive the significance of HPS in science teaching in four different manners: 1) HPS humanizes science education; 2)

HPS improves scientific literacy; 3) HPS enhance teachers' pedagogy; and 4) HPS boosts 21st-century skills. Based on the lens of the science teachers, they see HPS as crucial element in teaching science for the people and for the public good, as a tool in developing scientifically-minded individuals, as an instrument in improving their ways of teaching science and as a catalyst in developing future-ready learners.

The findings of this inquiry have important implications in science instruction in terms of practice, policies, and theories. For practical implications, teachers of science may utilize and integrate HPS in teaching science. Educators are encouraged to design HPS-based teaching strategies in explaining concepts, principles and ideas in science. For policy implications, the crystallized outcomes space can inform the existing science education framework in the Philippines of the inclusion of HPS as a separate subject in the science teacher education curriculum in the tertiary level. Since CHED has revised the Bachelor of Secondary Education (BSED) curriculum major in general science, the higher education institutions (HEIs) may integrated HPS as one of the specialization courses in the program. HEIs can also infuse HPS lessons in the course, The Teaching of Science (Teaching in the Specialization Field) for the holistic development of the prospective teachers. The findings also have implications to further enhance the HPS as a curricular innovation, as a course or as a separate degree program specifically in the Philippine setting. Likewise, the science teachers' conceptions are vital inputs in enhancing the teaching of HPS or similar courses in the teacher education institutions (TEIs).

For theoretical implications, the study added to the essence or phenomenon of HPS as an important tool in enhancing teachers' pedagogy and enhancing 21st-century skills. With HPS, teachers of science can enhance the way they plan and deliver their lessons. Additionally, HPS can serve as a tool in developing future-ready learners who can thrive and survive in the $VUCAD^2$ world.

The paper is also an indispensable contribution to educational research utilizing phenomenography as a research design. Likewise, the findings contribute to the Philippine literature on history and philosophy of science (HPS).

## Limitations and Future Directions

The study can be a prelude to further researchers in HPS and science education in the Philippine context since a dearth of studies has been done regarding this topic. Further studies on HPS in various dimensions may be considered to have a richer, more substantial and adequate HPS literature in the country.

Since the study is purely qualitative, other approaches to validate the findings of this research are recommended. Further, HPS instructors in the tertiary level may be considered participants in future studies to determine how they conceive the role of HPS in science instruction. Lastly, a survey questionnaire can be made in future studies based on the theme generated in this qualitative work.

■ ■ ■

## References

Abulon, E. L., & Balagtas, M. (2016). A phenomenographic inquiry on the concept of competence among Filipino teachers. *International Journal of Research Studies* *in Education, 5*(3), 91-104. https://doi.org/10.5861/ijrse.2015.1327

Arabatzis, T. (2017). What's in it for the historian of science? Reflections on the value of philosophy of science for history of science. *International Studies in the Philosophy of Science, 31*(1), 69-82. https://doi.org/10.1080/02698595.2017.1370924

Bachtold, M., & Munier, V. (2019). History and philosophy of science: A lever to teach energy at high school. In E. McLoughlin, O. Finlayson, S. Erduran, & P. Childs (Eds.), *Bridging research and practice in science education* (pp. 19-33). Springer, Cham. https://doi.org/10.1007/978-3-030-17219-0_2

Coelho, R. L. (2013). Could HPS improve problem-solving?. *Science and Education*, *22*(5), 1043-1068.

Forbes, C. T., Neumann, K., & Schiepe-Tiska, A. (2020). Patterns of inquiry-based science instruction and student science achievement in PISA 2015. *International Journal of Science Education*, *42*(5), 783-806.

Hendriks, F., & Kienhues, D. (2019). Science understanding between scientific literacy and trust: Contributions from psychological and educational research. In A. Leßmöllmann, M. Dascal, & T. Gloning (Eds.), *Science communication* (pp. 29 -50). De Gruyter.

Henke, A., & Hottecke, D. (2015). Physics teachers' challenges in using history and philosophy of science in teaching. *Science and Education*, *24*(4), 349-385. https://doi.org/10.1007/s11191-014-9737-3

Hottecke, D., & Silva, C. C. (2011). Why implementing history and philosophy in school science education is a challenge: An analysis of obstacles. *Science and Education, 20*, 293–316. https://doi.org/10.1007/s11191-010-9285-4

Hottecke, D., Henke, A., & Riess, F. (2012). Implementing history and philosophy in science teaching: Strategies, methods, results and experiences from the European HIPST project. *Science & Education*, *21*(9), 1233-1261. https://doi.org/10.1007/s11191-010-9330-3

Kampourakis, K. (2015). Succeeding Michael R. Matthews. *Science and Education, 24***,** 807–811. https://doi.org/10.1007/s11191-015-9770-x

Khan, S. H. (2014). Phenomenography: A qualitative research methodology in Bangladesh. *International Journal on New Trends in Education and their Implications, 5*(2), 34-43.

Macale, A. M. (2019). The role of history and philosophy of science in teaching the nature of science. *Journal of Nature Studies*, *18*(1), 52-64.

Matthews, M. R. (1994). *Science teaching: The role of history and philosophy of science.* Routledge.

Matthews, M. R. (2009). History, philosophy, and science teaching: The new engagement. In *Asia-Pacific Forum on Science Learning and Teaching* (10,1, 1-14). The Education University of Hong Kong, Department of Science and Environmental Studies.

Matthews, M. R. (2014). *Science teaching: The contribution of history and philosophy of science*. Routledge.

Matthews, M. R. (2017). In praise of philosophically-engaged history of science. *Science and Education, 26*(1-2), 175-184. https://doi.org/10.1007/s11191-017-9881-7

Matthews, M. R. (Ed.) (2018). *History, philosophy and science teaching: New perspectives*. Springer. https://doi.org/10.1007/978-3-319-62616-1

Morales, M. P. E. (2020). VUCAD2: A focus on the D's. *Asia Pacific Higher Education Research Journal, 7*(1), vii-ix.

OECD (2019). *PISA 2018 Assessment and Analytical Framework*. PISA, OECD Publishing. https://doi.org/10.1787/b25efab8-en.

Rogayan, D. V. Jr. (2015, September 10-11). *Kasaysiyensya: The HPS integration practices of science educators in a Philippine state university.* Paper presented at the International Conference on Science and Technology (S&T) Education. De La Salle University, Taft Avenue, Manila, Philippines.

Rogayan, D. V. Jr. (2018). Why young Filipino teachers teach? *Asia Pacific Higher Education Research Journal, 5(*2), 48-60.

Sanchez, J. R. B. (2016). Chemistry education and contributions from history and philosophy of science. *Ambix, 63*(4), 360-361. https://doi.org/10.1080/00026980.2016.1279422

Shahvisi, A. (2015). Tainted: How philosophy of science can expose bad science. *International Studies in the Philosophy of Science, 30*(2), 193-196. https://doi.org/10.1080/02698595.2016.1265869

Stefanidou, C. (2019). History and philosophy of science for citizenship: The case of life of Galileo by Bertolt Brecht. In P. Heering (Ed.), *Science as culture in the European context* (pp. 77-100). Flensburg University Press.

Stolz, S. A. (2020). Phenomenology and phenomenography in educational research: A critique. *Educational Philosophy and Theory*, *52*(10), 1077-1096. https://doi.org/10.1080/00131857.2020.1724088

Wieman, C. (2007). *Science education in the 21st century using the tools of science to teach Science*. University of British Columbia and University of Colorado, Boulder.

Yalaki, Y., & Cakmakci, G. (2010). A conversation with Michael R. Matthews: The contribution of history and philosophy of science to science teaching and research. *Eurasia Journal of Mathematics, Science & Technology, 6*(4), 287-309.

■ ■ ■