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Looking back at "our science" and "our history": an exploration of Korean preservice science teachers' encounters with East Asian history of science

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Abstract

Despite the long-standing interest among science educators in using history of science in science teaching, little has been discussed around whether and how non-Western histories of science could be incorporated into science education. This study considers some opportunities and challenges of addressing East Asian history of science (EAHOS) in the science teacher education context, drawing on postcolonial science studies and global history of science. Eight undergraduate preservice science teachers (PSTs) participated in sessions on EAHOS. Our aim was to investigate the PSTs' perceptions relating to the nature of EAHOS and its relevance to science teaching. Using interviews and reflective essays, we explore the tension coming from their dual positions as science teachers and East Asian people as they entered into the unfamiliar territory of EAHOS. When they were considering themselves specifically as science teachers, they tended to focus on the aspects of EAHOS as knowledge and concluded that it has little to do with achieving the aims of science teaching because is not part of modern science. On the contrary, when they were talking about their roles as teachers in general, they were able to come up with several educational benefits that EAHOS can offer to students, particularly in its relation to worldview and history. Additionally, several mixed feelings were expressed about the way EAHOS is often portrayed as "our" history about "our" science. Overall, the experience of exploring and discussing EAHOS provided the PSTs with an opportunity to critically reflect on science education and their responsibility as teachers in the context of broader society and culture.

Keywords History of science · Science teacher education · Non-western science · East Asia · Global history of science

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Many peoples in the pre-modern world developed their own ways of making sense of nature. Some of these have perished over time and have been replaced by modern European science, while others have survived and still have some influence on human lives and culture. A relatively well-known example is Arabic science, which is known due to its contribution to the formation of modern science, thus leading to its occasional appearance in science curricula. Among the many non-Western histories of science, this paper focuses on the East Asian history of science (EAHOS), particularly the history of scientific thought, activities, and artifacts in China and Korea (see Sivin (1988) and Kim (1982) for an overview of EAHOS as an academic discipline). We use "science" loosely to refer to "systemic, coherent discourse about natural phenomena that strives toward an ideal of abstraction and objectivity." (Sivin 1988, p. 43) This definition also echoes with Matthews's (2009) characterization of science as "the effort of people and societies to identify, understand, and 'make sense of' the objects and processes in the world around them; to tabulate the properties of natural things and processes; and to ascertain how causal mechanisms in the world operate" (p. 9). Such broad working definition of science encompasses not only physical sciences, astronomy, and medicine, but also departments such as feng shui (Chinese geomancy, or the "art of siting"), that do not precisely correspond to any modern science disciplines in terms of their aims and methods but still have some conceptual foundations and practical applications. Given that the knowledge about nature was created, developed, and utilized in a social and intellectual background that was different from the West, it would be less useful (if not impossible) to attempt one-to-one correspondences between the areas and concepts in East Asian science and modern Western science—an issue to which we will come back when discussing our empirical findings.

Two aspects of East Asian science make it distinctive among other non-Western sciences. First, it emerged and developed on very different metaphysical foundations than those of the modern science that we teach and learn in schools. For the most part, East Asian views on nature were grounded on Confucianism that originated in China and spread to Korea, Japan, and Vietnam (Berthrong 1998). Given this historical origin, it is no surprise that the knowledge and practices of East Asian science are not so much part of modern science as those of Arabic science are. Nevertheless, EAHOS is still important as a knowledge system that East Asian people used to explain and understand the natural world. Second, the legacy of East Asian traditional science is evident as an influence in people's lives until today, both within and outside the East Asian world. For example, China and South Korea still have specialized higher education institutions to train practitioners of traditional medicine, and many people regularly visit licensed clinics to get treatments in acupuncture, moxibustion, cupping, and herbal medicines (Park et al. 2012). Another good example is feng shui, which originated from ancient Chinese cosmology that was deeply intertwined with the political and social structure of traditional society (Bruun 2008). The phrase *feng shui* literally means "wind and water," and it concerns the invisible force *qi* that permeates everything in the universe. Since the 1990s, the idea of feng shui has gained popularity and had an impact on practices outside East Asia. Believers in feng shui feel that it is effective when building houses and businesses, which has even resulted in its occasional inclusion in architecture curricula (Matthews 2018). Feng shui also has practical implications for landscape painting, garden making, and martial arts (Parkes 2016). In sum, the parallel development of EAHOS with Western science and its lasting influence are good reasons to consider it in relation to science education, particularly in the East Asian context.

Authors from diverse academic disciplines have acknowledged the potential value of EAHOS in educating scientifically literate citizens. American philosopher Martha

Nussbaum, in her book *Cultivating Humanity* (1998), refers to an innovative university course where the Chinese history of science was used to cultivate world citizenship. In this course, a team of four academics from philosophy, history of science, art history, and comparative literature at an American university designed a course focusing on achievements in ancient Greece and Rome across art, science, and politics, while comparing it with those in China during the same historical period (Nussbaum 1998). This course, says Nussbaum (1998), allowed students to understand what was distinct about the Western tradition from a fresh point of view, partly through contrasting it to the Chinese tradition. As science historian Yung Sik Kim (2001) claimed, by illuminating the Western scientific tradition from the perspective of East Asia, we can not only "better understand the East Asian science," but also "see what happened in the West in a new light" (p. 78). He also highlighted that it is important to understand the science of East Asia in the historical, political, and cultural contexts in which it is embedded; otherwise, only the superficial factual similarities would be given attention. Derek Hodson (2014) also acknowledged that EAHOS can contribute to the prevention of scientism, universalism, and so forth. Most recently, Michael Matthews (2019) made an extensive case for how critical reflection on feng shui in science classrooms can contribute to cultivating scientific habits of mind and therefore improve the cultural health of society.

A crucial step in considering possible educational applications of EAHOS in classrooms is to understand how teachers conceive of the key concepts and pedagogical issues related to EAHOS. Within the current system of initial teacher education in Korea, however, EAHOS is typically not covered in science or history teacher education programs. As a result, teachers' perceptions and the potential values of EAHOS remains uncharted in both science education and history education research. To fill this gap, we introduced Korean preservice science teachers (PSTs) to EAHOS as part of their coursework and encouraged them to reflect on whether and how it might relate to science education. Our aim is to understand the PSTs' experiences of encountering their own cultural legacy as people who were educated and trained in modern scientific culture. The study aimed to answer the following two questions:

1. What do the PSTs perceive as the nature of EAHOS as they learn about it in a history of science course?
2. What is the perceived relevance of EAHOS to science teaching as they learn about it in a history of science course?

While the first question concerned the different ways that the PSTs made sense of EAHOS as they learned it (i.e., when wearing the "learner's hat"), the second question took a step further to investigate how such perceptions are translated into ideas about the relevance of EAHOS to science teaching (i.e., when wearing the "teacher's hat").

Theoretical underpinnings

Sociocultural theory

Our inquiry was informed by sociocultural theory, which views learning and meaning making as complex social processes that occur between the individual and a situation (Lave and Wenger 1991). Sociocultural theory posits that neither the scientific study of the world nor our learning about it is separable from various levels of organizations ranging from the classroom to the global community (Lemke 2001). In this sense, taking a sociocultural perspective is useful for considering the PSTs' perceptions about EAHOS in relation to their prior knowledge about and experience with it as a science student in an East Asian country. In addition, sociocultural theory provides us with a useful tool to appraise the "science" found in EAHOS as a social and cultural product rather than something primitive and superstitious when compared to modern science. Considerations of sociocultural factors are particularly important in the teacher education context (Putnam and Borko 2000), especially given that PSTs' perceived value of EAHOS in relation to school science would be influenced by the broader social context of science and science education.

Postcolonial science studies

The sociocultural lens brings us to the question of what should be taught in science classrooms, particularly in places where some indigenous knowledge coexists with modern scientific culture. On this issue, we position our investigation in the domain of postcolonial studies of science and technology (e.g., Harding 2011). Postcolonial theory generally aims at accounting for and deconstructing the centrality of Europe relative to other regions that emerged as a result of European colonial rule (Seth 2009). Douglas Medin and Megan Bang (2014) views that the mainstream perspectives on science emphasize the unique status of Western science as being objective and rational, which is lacking in "less advanced" cultures. On the presentation of history of science in schools, they claimed that "Western (Ethno-)science represents one set of orientations among many and one set of values among many. These values need to be made explicit and the possibility of a broader set of values acknowledged." (p. 31) As Teresa Arámbula Greenfield (2005) criticized, science teacher education exclusively focused on WMS might perpetuate teachers' inattention to cultural issues in education. Considering that modern science itself has been co-constructed with colonialism and Eurocentrism (Seth 2009), indigenous modes of inquiry such as the ones found in EAHOS have the potential to prompt teachers' critical reflection on the way science is represented in the curriculum.

Global history of science

The rise of postcolonial theory has recently been followed by the emerging interest in the "global history of science" among historians of science (e.g., Roberts 2009) and science education scholars (e.g., Gandolfi 2019). These scholars assert that "the achievements of modern science must not blind us to the complex history whereby its institutions, practices, and visions of nature came both to be shaped by, and to have a formative impact on, the global context in which they developed." (Roberts 2009, p. 10) From a postcolonial standpoint, Manolis Patiniotis (2013) criticized the tendency to view the Enlightenment as a central event in human history and its reception in other regions as a process of restructuring society on the basis of reason. Instead of viewing science as a product of a specific nation, civilization, or ethnic group, global history of science is mainly concerned with "the transmission, exchange and circulation of knowledge, skills, and material objects." (Fan 2012, p. 251).

Gandolfi's (2020b) study is an example of how global history of science can help to rethink the "science" in what we call the nature of science (NOS) and help to deepen NOS understanding. In one of the modules that she implemented with a secondary school teacher in England, they used a narrative that the compass was first invented in ancient China and then was spread to Europe through the Silk Road. They then asked students to reflect on the impact of such a cultural exchange of scientific knowledge on diverse aspects of human lives such as economy, politics and modern technology. Her findings suggested that such an approach resulted in students' improved understanding of diversity, cultural exchanges and collaborations, and financial, ethical, and political aspects in science. She also found that engaging in the development of such intercultural lessons benefited the teacher's professional development and self-efficacy for teaching NOS (Gandolfi 2020a). For our work, we shared the core arguments of postcolonial theory and global history of science and incorporated them into the course design and the interpretation of data, as will be further described below.

Non-Western histories of science and indigenous knowledge

Let us consider the following few questions: "How do people in different times and places—different cultures—imagine nature and mankind's relation with it? What realities and values are reflected in this ideal construction? How is it transformed into concrete technical practice? How does experience of the external world come to be split into specialized domains of knowledge? How do the latter, and the larger vision they inform, change?" (Sivin 1988, p. 42) With no prior knowledge, these questions might be read as alluding to the so-called cultural embeddedness and human aspects of science, understandings of which are emphasized in the recent curriculum documents (e.g., NGSS Lead States 2013). In fact, these are the questions asked by prominent sinologist Nathan Sivin to describe the main interests of historians of Chinese science. The resemblance between the questions being asked about Western science and East Asian science suggests a deep resonance between the two histories; After all, both are interested in unraveling how humans made sense of the material world in a certain geographical area in a specific period and how this has evolved over time.

The universalist positions about science maintain that Western modern science holds a unique epistemological status that is clearly superior to that of indigenous knowledge systems (Loving 1995; Matthews 1994). On the contrary, the multiculturalist positions recognize the value of indigenous knowledge systems as legitimate forms of inquiry and advocate their inclusion in the science curriculum as a way of decolonizing the curriculum (Lewis and Aikenhead 2001). In this paper, we endorse more recent views that reconcile the universalist-multiculturalist dichotomy. Yeung Chung Lee's (2018) approach is exemplary. His "cross-cultural" view does not challenge the special status of Western science, but at the same time, also acknowledges "the contribution of multicultural knowledge systems in understanding and harnessing nature, which, through technology diffusion, influence technological and scientific development in other cultures" (p. 503). Hansson (2018) echoes this view by underscoring the importance of recognizing the value of both Western and indigenous systems. According to these views, it becomes a crucial task to critically reflect on the Western and indigenous systems from a comparative point of view. We assert that such a conceptualization of Western science and indigenous science can provide more constructive ways to address the histories of non-Western sciences in science (teacher) education.

Addressing East Asian traditional science in science education

Although not much has been disseminated to the Anglophone world, there has been sustained interest and effort to utilize East Asian traditional science in classrooms, particularly in mainland China and Korea. Australian science educator Michael Matthews (2019) recently published a comprehensive investigation on the relationship of feng shui to science education. Based upon a detailed historical reconstruction of feng shui and its contemporary meaning in East Asian countries, he argued that feng shui can serve as an excellent cross-disciplinary topic for teaching the nature of science, primarily by reflecting on why it is a pseudoscience and cannot be considered as a legitimate scientific theory (Matthews 2019). He points out that although feng shui has simulacra of the nature of modern science in terms of its method, experiment, theory, and social organization, it lacks key elements of science such as controlled and reproducible experimentation, and the production and verification of testable claims (Matthews 2019). Nevertheless, Matthews acknowledges that feng shui can be part of science lessons and offer opportunities to critically examine what science is and thereby contribute to the “cultural health” of society (Matthews 2018, p. 34).

Yeung Chung Lee (2018) drew on three examples of traditional Chinese technology—ceramics, fermented food, and variolation—to propose several benefits of a cross-cultural approach to science education from a science-technology-society (STS) perspective. He asked three questions in each of the three contexts: (1) “How did cultural contexts influence the development of traditional technology before the emergence of science?” (2) “What role did cross-cultural influences play in the evolution of traditional technology and its interactions with science?” and (3) “What insights can be drawn from these case studies to inform culturally relevant STS education?” (p. 495) Discussing how an examination of these questions can enrich science teaching, Lee stressed that “cross-cultural STS education takes a step beyond the existing multi-cultural science education paradigm by focusing more on the similarities, interconnectedness, and interactions among different cultures than on cultural disparities” (p. 511). Despite his focus on technological (rather than scientific) aspects in these examples, Lee’s discussion is useful in that it provided an important way that non-Western history of science (HOS) can contribute to today’s science education: by providing a bridge between paradigmatic Eurocentric science education and indigenous knowledge (Lee 2018).

Although the current literature on the use of EAHOS in science teaching has hinted at some potential benefits, studies have been focused on a small number of issues, such as using historical anecdotes or artifacts mainly to promote students’ interest in science. Research has also been limited to the perceptions of teachers and students in non-intervention settings. These limitations call for more research efforts to understand the diversity of ways that EAHOS could relate to science education and particularly to science teacher education programs.

Research methods

This study adopted an action research design wherein the two authors took on the role of participant-observers, Song as the main instructor and Park as a teaching assistant. Grounded on the sociocultural and postcolonial theories, we were interested in how the

PSTs make sense of EAHOS as they learn about it, especially in relation to Western science and the current practice of science education which is mostly based on Western science.

Course context and design

This study took place in a large research university in Korea that has a science teacher preparation program. The study was situated in a one-semester course titled History of Science for Teachers, a three-hour-per-week undergraduate course taught during the fall semester of 2018. A major interest of us as teacher educators was to design a course where PSTs could learn the cultural and historical contexts of science across the globe, and reflect on their pedagogical implications. Although appreciating the role of indigenous science and its history in science curricula would not be possible without a proper understanding of the content of indigenous science, in most countries, indigenous science is not often addressed to PSTs. In Korea, science teacher education programs frequently offer courses on history of science, but they are mostly focused on Western science (Song and Joung 2014). As an early effort to incorporate EAHOS into the history of science course, we aimed to explore the potential of such a course in developing PSTs' awareness of the relationship between indigenous science, Western modern science, and history of science in the East Asian context.

Informed by global history of science, we brought together what Soraya de Chadarevian (2009) called "microstudies" and "big picture" accounts in history of science in our course design. The former focuses on localized and specific achievements in science, whereas the latter is concerned with the broader social, cultural, political contexts at a global scale (Orthia 2016). To address both approaches to HOS, the first half of the course was focused on Western HOS, after which the PSTs were introduced to EAHOS and its relation to the broader context of world history. The course started with a general introduction to HOS, nature of science, and an examination of the recent science curriculum documents in terms of HOS. Throughout the seminar-style course, the PSTs engaged in various pedagogical activities about HOS, such as designing a lesson using HOS and giving microteaching sessions. Within the semester-long course, the present study focuses on the sessions of Weeks 10–12, where the main subject was the East Asian and Korean histories of science. During this phase of the course, The PSTs made presentations about several key topics in EAHOS as outlined in the course syllabus. These presentations were based on a course text provided by the instructor, but they were encouraged to use external content and resources outside of the text. The main topics of EAHOS covered in the class are described in Table 1.

To promote a global and "cross-cultural" (Lee 2018) understanding of HOS, we used several pedagogical tools and strategies throughout the course. In planning the course, we were particularly mindful of addressing the variety of current discussions on EAHOS by including not only the scientific ideas and objects but also its cultural, historical, and controversial aspects. The timeframe covered in the course was extensive, ranging from the early establishment of views on nature in ancient China to the transmission of European science to East Asia in the seventeenth century, and then to the rapid growth of science and technology in Korea around the 1960s. A significant portion of the class time was devoted to discussing science in pre-modern China and Korea, which was largely hinged on the Confucian view of nature, humans, and society (Kim 2002). In particular, we used two instructional tools to engage the PSTs in EAHOS. First, in each session, we gave the PSTs some questions (see Table 1) to elicit their reflections about EAHOS besides merely reviewing historical facts. The intention

Table 1 Examples of course content related to EAHOS

1. "Science in Ancient China"
Session summary: Two competing models of the universe: Canopy-Heavens hypothesis (*gaitian shuo*) and egg-like hypothesis (*huntian shuo*), and visual proof of the Pythagorean theorem for the 3:4:5 triangle in *The Arithmetical Classic of the Gnomon and the Circular Paths of Heaven* (*Zhoubi Suanjing*; c. 500–200 BC; figure shown below)
Reflective questions: 1. Discuss how traditional Chinese mathematics is different from ancient Western mathematics. 2. Discuss the similarities and differences between traditional Chinese astronomy and modern Western astronomy.
2. "Science in traditional Korea"
Session summary: The printing technologies of *Tripitaka Koreana* (81,258 wooden printing blocks from thirteenth century) and *Jikji* (world's oldest extant book printed with movable metal type), diverse hypotheses on the function of Cheomseongdae (Asia's oldest surviving astronomical observatory), and the background to scientific achievements in the early fifteenth century during the reign of Sejong the Great
Reflective questions: 1. Discuss why the scientific achievements of Sejong the Great's reign did not continue after his death. 2. Read the competing interpretations of the role of Cheugugi (Korean traditional rain gauge) and discuss what its making and distribution could have meant in the social and political context.
3. "Science in modern East Asia"
Session summary: The role of the Italian Jesuit priests in transmitting European science to China in the seventeenth century, Dutch influence on the reception of Western science in Japan, the fast rise of Japanese science and technology since the Meiji Restoration (1868), the achievements of major scientists and inventors in colonial Korea, and the "science movement" by colonial Korean engineers
Reflective questions: 1. Discuss the various views on the influence of Japanese colonialization on the modernization of Korea. 2. Investigate the differences between China, Korea, and Japan in how they received modern science from the West.

was to encourage the PSTs to consider their learning of specific artifacts, events, or historical figures in the broader social, historical, political contexts in East Asia and beyond. Second, the PSTs were frequently referred to an illustrated integrated timeline of HOS, where major events in EAHOS were presented in parallel with major events in the history of Western science, world politics and culture, and the general history of Korea (a simplified version shown in Table 2). We intended to direct the PSTs' attention to the wider historical context in different geographical areas and in different aspects of human lives, hoping that doing so would lead to a nuanced and contextualized appraisal of EAHOS.

In the class, we were cautious not to impose our own beliefs about the scientific or educational values of EAHOS. Instead, we encouraged the PSTs to express their own opinions about two overarching questions in each class: How does this EAHOS topic compare with Western HOS covered earlier in the course? and How do you think this EAHOS topic could be used in the high school science classroom? These questions were to encourage the PSTs to evaluate and interpret EAHOS content in terms of both HOS in general and teaching practice, rather than just taking the EAHOS content as mere knowledge to memorize for exams. Each presentation was followed by a whole-class discussion on the topic moderated by the instructor.

Participants

Participants were eight undergraduate PSTs enrolled in the course (Table 3). Five (62.5%) were physics education majors, two (25%) chemistry, and one (12.5%) biology; all participated voluntarily with informed consent. Two PSTs in their fourth year had recently

Table 2 Integrated timeline for Western HOS, EAHOS, Korean history, political history, and cultural history (simplified from original)

Western science	400 BCE Democritus, the theory of atoms	c. 150 Ptolemy, the geocentric model of the universe	1088 University of Bologna starts to teach medicine	1543 Copernicus, geocentric model of the universe	1687 N, *Principia* 1765 W, improved steam engine	1803 Dalton, atomic theory 1859 Darwin, *The Origin of Species*	1912 Wegener, continental drift theory 1916 Einstein, general relativity theory	2001 Human genome sequence released 2016 Gravitational waves detected
East Asian science	c. 165 BCE First known record of sunspots (China)	105 Cai Lun invents paper (China) c. 647 Cheomseongdae built (Korea)	1024 Record of sunspots in *Goryeosa* (Korea)	1337 *Jikji* (the oldest known book printed using metal type (Korea)	1601 Italian Jesuit priest Matteo Ricci arrives in Peking (China)	1861 Kim Jeong-ho, Daedongyeojido (first detailed map of the Korean peninsula)	1949 Yukawa Hideki becomes the first Nobel laureate in Japan	
	500 BC	0	1000	1400	1600	1800	1900	2000
Korea	57 BCE Silla founded 37 BCE Goguryeo founded	396 Gwanggaeto the Great of Goguryeo defeats Baekje	1392 Joseon founded, replacing Goryeo	1446 Hangul (Korean alphabet) created by Sejong the Great	1636 Qing invasion of Joseon	1818 Jeong Yakyong writes *Mokminsimseo*	1905 Korea colonialized by the Japan-Korea Treaty 1950 Korean war	2002 FIFA World Cup Korea-Japan
World politics	403 BCE Warring States period began (China) 27 BCE The Roman Empire began (Europe)	184 Yellow Turban Rebellion broke out (China) 395 Roman Empire divided (Europe)	1096–1270 Crusades (Europe) 1368 Ming dynasty founded (China)	1438 Inca Empire founded (America) 1517 Protestant Reformation started	1762 Rousseau, *Social Contract* (France) 1776 Independence of USA (America)	1840 First Opium War 1867 Marx, *Capital* (Germany) 1868 Meiji Restoration (Japan)	1914 World War I 1957 Launch of Sputnik I (Soviet Union)	

Table 2 (continued)

	500 BC	0	1000	1400	1600	1800	1900	2000
World culture	438 BCE Parthenon completed (Greece)	80 Colosseum completed (Rome)	1163 Notre Dame Cathedral completed (France)	1541 Michelangelo, *The Last Judgement* (Italy)	1725 Vivaldi, *The Four Seasons* (Italy)	1869 Tolstoy, *War and Peace* (Russia)	1917 Duchamp, *Fountain* (USA) 1949 Orwell, *Nineteen Eighty-Four* (UK)	

Table 3 Participant backgrounds

Name	Major	Gender	Year	School internship	HOS backgrounds
S1	Chemistry	Male	4	No	High interest. Read a few related books
S2	Physics	Female	2	No	High interest. Took an introductory philosophy of science course at the university and read a few related books
S3	Biology	Female	1	No	Fair interest. No prior engagement
S4	Chemistry	Female	4	Yes	Low interest. No prior engagement
S5	Physics	Male	2	No	Low interest. No prior engagement
S6	Physics	Male	4	Yes	Fair interest. Took an introductory philosophy of science course at the university and read a few related books
S7	Physics	Male	2	No	Fair interest. No prior engagement
S8	Physics	Male	2	No	Fair interest. Took an introductory philosophy of science course at the university

finished their school internship, and all PSTs had some science teaching experience in formal and/or informal settings, for example through volunteer mentoring and private tutoring. Participants had diverse backgrounds in terms of their interests and experience in HOS. Four (50%) had prior experience reading books or taking courses related to HOS and/or philosophy of science, and two (25%) expressed high interest in HOS. The books or courses they mentioned were mainly about the standard "Western" history and philosophy of science, so their knowledge about EAHOS was limited and mostly came from the Korean history classes taken in high school or undergraduate studies, rather than from science-related classes or books.

In view of our sociocultural research focus, it should be noted that the participants came from strong natural science backgrounds where the majority of their university coursework consisted of undergraduate-level scientific subjects such as classical mechanics, electrodynamics, inorganic chemistry, and molecular biology. This suggests that they were educated in modern scientific culture throughout their undergraduate education and were used to the concepts and methods of modern science. During our course, however, what they encountered was the history of science in East Asia, which is based upon a markedly different set of axiological, metaphysical, and methodological foundations from the "science" that was familiar to them. It is thus crucial to note that while the PSTs grew up in East Asian culture, in terms of their views of nature and science, they are no longer "natives" to the traditional East Asian views. Our main aim was to investigate looking in reverse from the Western, modern scientific standpoint back at traditional East Asian culture, a point of view that has been little investigated in the cultural studies of science education.

Data collection

Within the dataset from a larger research project that investigated PSTs' experiences of HOS and its use in teaching practice, a subset of data relevant to the research questions was used. Data sources included students' reflective essays, semi-structured interviews, and in-class discussion. At the end of the semester, participants wrote reflective essays of two to three pages. This was prompted by cue questions such as "How would you compare the Western and East Asian histories of science that you have learned?" "Do you think students should learn EAHOS?" and "How, if at all, could EAHOS be used in secondary science classrooms?" At the end of the semester, four participants were invited for a semi-structured interview. Interviewees were purposefully selected based on their engagement in the course and the need to elaborate the views that they had expressed in other data sources, particularly their reflective essays. Interview questions were focused on their perceptions about East Asian science in each historical period, views on the comparison of Western HOS and EAHOS, and whether and how EAHOS could be taught as part of the science curriculum. Along with these common questions, personalized questions were asked to elaborate on their responses in the reflective essays, presentations, and discussions during the class. All interviews were conducted by two course TAs approximately a month after Week 12. Each interview lasted 60 to 90 min.

In addition to the above, field notes were taken throughout the semester by the first author to capture contextual information about the presentations, activities, and conversations, as well as personal thoughts and queries. Informal communications between the PSTs and researchers during and after class, when considered relevant to the study, were also recorded in the field notes. Although this study focused on the PSTs' perceptions about EAHOS specifically (as opposed to HOS in general), as will be examined later, these perceptions tended to be tightly connected to their ideas and beliefs about HOS in general (incluuding Western HOS) and those about science teaching. We therefore needed to consider the data from the entire semester to have a comprehensive and holistic understanding of each PST's ideas and perceptions. Due to the nature of this research where we investigated our own course and students, we were conscious of ensuring volunteerism by recruiting participants in the absence of Song (who was the main instructor and therefore was responsible for grading) and allowing the access to the list of the agreed participants only to Park. The institutional review board at Seoul National University reviewed and approved the procedures for participant recruitment, data collection, and data storage and use.

Data analysis

All collected data were read multiple times to generate initial codes describing PSTs' ideas. Transcripts were imported to the qualitative data analysis software MAXQDA® 2018 (release 18.2.0) and then analyzed by the first author. Codes were inductively generated, considering the exploratory nature of the study and the scarcity of previous research on the subject. Coding was conducted with the two research questions in mind: the PSTs' characterizations of EAHOS and their perceptions about the relevance of EAHOS to science teaching. We conducted a standard thematic analysis of the reflective essays and interview transcripts (Braun and Clarke 2006). Initial codes for how PSTs described EAHOS were coded following several coding strategies such as in vivo codes (e.g., "technolog-ish"), versus codes (e.g., "our thing vs their thing"), and typical descriptive codes as appropriate. After this initial coding process, themes were generated by reassembling and categorizing the codes in light of the research question. A draft codebook was created during this phase and modified through multiple iterations of coding until no new codes appeared. Themes were then interpreted as relating to each of the three main aspects of EAHOS—knowledge, worldview, and history—which emerged inductively. We frequently used analytic memos (Saldaña 2013) during the process to record emergent ideas related to codes and categories.

Reliability was established through multiple readings of the transcripts and the refinement of the codebook over time (Franklin et al. 2010). Codes and interpretations of PSTs' perceptions were triangulated by cross-checking among the different data sources and regular discussions between the authors. While the analysis mainly focused on the themes that were common across participants, we also looked at how the themes unfolded differently for each participant and whether there were any contrasting views across participants, which allowed a richer description of their perceptions (Yin 2017).

Researcher positionality

It is important for researchers investigating their own practice to consider their positionality in relation to the study (Heikkinen et al. 2007). Given the nature of our study as an action research project on the cultural aspects of science education, our aim was not to pursue pure objective knowledge that transcends the viewpoints of ourselves as teachers and researchers. Both of us, like our participants, grew up in a culture where traditional Korean medicine (*haneuihak*) practices such as herbal medicine, moxibustion, and acupuncture existed side by side with Western medicine. In the meantime, the two of us shared an experience of doctoral training in the UK, where a significant portion of Western science emerged since the Scientific Revolution. Although we studied there at different times (the late 1980s for Song and late 2010s for Park), we both had an interest in the history of science in Europe, which later developed into a broader interest in historical and cultural approaches to science (education) in Europe and East Asia. With a commitment to the value of cultural history of science in science teacher education, our own epistemology aligned with the postcolonial and global perspectives on science on which this study was theoretically based. Such backgrounds of us allowed considering the PSTs' experiences from both East Asian and European points of view. In addition, as teacher-researchers, our "insider" position (Herr and Anderson 2015) enabled us to gain a deeper and more nuanced understanding of their ideas about EAHOS. Our own understanding about EAHOS in relation to science education reported in this paper is thus, to a certain extent, the product of designing, enacting, and reflecting on the course, providing lessons and posing new questions for our future actions as teacher educators (Heikkinen et al. 2007).

Perceived nature and characteristics of EAHOS

Three major themes were identified in the way PSTs perceived what EAHOS is and what it is about: science/technology distinction, human-nature relation, and pride and prejudice. The analysis showed that each of these themes was pointed at knowledge, worldview, and historical aspects of EAHOS.

Knowledge: Is it about science and/or technology?

The first theme in PSTs' perceptions about EAHOS pertained to its nature as a body of knowledge. When speaking about EAHOS as knowledge, the prevailing image was that it is a collection of technical, instrumental, and empirical knowledge that had been developed primarily for everyday use by East Asians. They also mentioned that the content of EAHOS seemed to mainly include knowledge about tools, instruments, and counting systems which, to them, were concerned more with technology, engineering, and invention than with science. This is best represented in S2′s remark where she described Chinese and Korean traditional science as "technolog-ish" and S1′s where he felt it to be "artifacts and technology … [hence] just an enumeration of information without much [scientific] content" (reflective essay). PSTs noticed that East Asian science is not specialized and not theoretically articulated, as seen in the following remarks:

> The biggest difference I felt while learning the Western and Eastern (Although the term "East Asian" technically refers to the geographical region narrower than what "Eastern" refers to, the two are often used interchangeably in the day-to-day Korean language found in these quotes. The word "Eastern" should therefore read "East Asian" in these occurrences.) histories of science was that, whereas Western HOS resembles "science" as we think about it today, EAHOS is focused more on "technology," unlike science as we think of it now. (S2, reflective essay)
>
> The Western HOS describes changes in theories and concepts in the individual disciplines of physics, chemistry, biology, geology, and astronomy, but EAHOS explains technological objects and inventions grouped by period. (S1, reflective essay)
>
> There were a lot of technological objects [in EAHOS]. In fact, it seemed that rather than making these objects based on an understanding [of scientific principles], they made them based on experience or by chance. For example, when they were making

things like bells, they would have accumulated some experience, but weren't they made by luck [among many trials]? (S1, interview)

Whereas the PSTs perceived Western HOS as a "history of ideas," EAHOS was rather perceived as a "history of things," as if East Asian people did not have scientific theories at all. This can be better understood when we recall that the representation of EAHOS in documentaries and popular books often features "things," such as the four great inventions (the compass, gunpowder, papermaking, and printing) of ancient China and specific artifacts (e.g., observatories, sundials, and star maps) that usually come with a commentary that these were invented and used centuries earlier than they were in Europe. This suggests that the respective public images of EAHOS and Western HOS forming in ways that highlight different categories could have resulted in their perception that they cannot be legitimately compared for.

Many PSTs tended to draw a clear line between science and technology, resulting in their perception of EAHOS as a history of technology rather than a history of science. In other words, PSTs seemed to have established, from their experiences with Western science, some "comfort zones" in terms of what could be called science and have used these as demarcation criteria for EAHOS. In particular, PSTs found that East Asian science lacks a theoretical character and regarded it to be more about technology than science. This indicates that having theoretical elements is considered one of the necessary conditions to count as science, as reflected in the remark by one PST: "I felt that EAHOS doesn't have many scientific theories, so thought it's like history of technology rather than history of science." (S1, reflective essay).

A further aspect of the science-technology distinction was the PSTs' feeling that the primary aim of science in pre-modern East Asian societies seemed to have been making practical contributions to human lives by "increasing people's quality of life" (S3, reflective essay) and "seeking more convenient lives for laypeople" (S5, reflective essay). These characteristics of EAHOS became evident to PSTs when it is compared to the Western HOS. For example, S3 used the example of astronomy to compare the nature of Western and East Asian ways of thinking. She explained that EAHOS lacked the "why" and "how" questions but focused on describing phenomena that are relevant to people's everyday lives in a superficial, non-analytical way. She said: "[East Asian people] attempted to utilize astronomical phenomena by relating them to daily lives rather than investigating the causes. Therefore, it is not easy to find any ultimate questions such as 'why?' or 'how?'" (S3, reflective essay).

Worldview: an alternative way of imagining nature–human relations

Given that EAHOS reflects how the East Asians in different time periods imagined nature-human relationships and how their views about nature existed in harmony with society, religion, and so forth, characterizing EAHOS as a worldview has resonance with science education. The significance of worldview in relation to school science has been acknowledged by the works of Glen Aikenhead (1996) and Masakata Ogawa (1995), among others. William Cobern (1996) defined worldview as "metaphysical levels antecedent to specific views that a person holds about natural phenomena, whether one calls those views common-sense theories, alternative frameworks, misconceptions, or valid science" (p. 585). Our analysis suggested that the aspects of EAHOS as a worldview, attitude, or perspective that East Asian people had toward nature comprised an important part of their perceptions. Pointing to the attitudes that pre-modern East Asian people had toward nature, some PSTs mentioned that the contrast between the West and East Asia was a particularly impressive aspect throughout the course. They discovered several points of divergence between East Asian science and Western science when taken as worldviews. For example, S6 acknowledged the holistic worldview represented in East Asian science versus individualistic worldview of the West:

> My impression about EAHOS is that they [East Asian people] tried to understand the world from a very holistic perspective. They tried to get a sense of the origin of all things rather than individual objects and the system of the entire universe rather than a single phenomenon. I think we can find some meanings from those aspects. (S6, reflective essay)

Besides, they also made several remarks on how the East Asian and Western people viewed nature in relation to humans. This became most evident in one class where the PSTs engaged in a discussion about the concept of "nature as 'natural'" in traditional Chinese science. This is reflected in the literal meaning of the word "nature" (*ziran*)—to be so of itself. To East Asian people, nature did not mean something to be analytically and causally investigated as a source of learning (see Ken Kawasaki (1996) and Hongming Ma (2012, Chapter 2) for further discussions on this matter.). Let us briefly refer to an example that was introduced during our class (originally from Kim, 2014, p. 16), to illustrate this notion more concretely:

> Zhu Xi spoke of the fact that once a cart has started to move, no great exertion of force is needed to keep it moving; he argued that, in studying also, a great exertion of effort is needed only at the beginning, after which it becomes easy. Similarly, to explain that when impurities enter the mind it loses "sincerity" (*cheng*) and falls into self-deception, he used the analogy that when gold is mixed with a small amount of silver the whole bulk of gold loses its worth as gold.

Here, two natural phenomena that could have each amounted to the law of inertia (in the case of moving cart) and some knowledge about matter (in the case of gold with impurities) to the eyes of seventeenth-century Europeans are instead used as sources of analogical reasoning—the target being "teachings" about human life and ethics. Several PSTs were fairly impressed by such a mode of thinking and mentioned it as a definitive feature of EAHOS in the end-of-term reflective essay:

> The most impressive thing was the attitudes with which people understood nature in the West and East … Although it's true that the inquiring mind of the West of course became the source of scientific advances in the past, I thought the East Asian people's wisdom about keeping a good mind and learning from nature provided a basis on which we can accept science justly and use it wisely. I think that the fact that the East Asian people put much value on courtesy and care for others even today comes from the ancestors' habits of learning from nature. (S5, reflective essay)
>
> I thought the biggest contrast was the religious value system and the views about the world. In the West, there was the omnipotent creator called "God" who created everything in the world, and they assumed that there are natural laws that things follow, so they granted a great value in investigating these laws, but in China, I think that more in-depth investigations were made into humans rather than natural laws. (S7, reflective essay)

In these statements, we can see that the PSTs were trying to find connections both between EAHOS and diverse aspects of human lives, such as worldviews, morality, and religion, and with today's cultural norms in East Asian societies. Although many of these were not mentioned explicitly in the class, the PSTs were found to have developed their own views about EAHOS based on their prior knowledge and experience as people born and raised in East Asian culture.

History: the undercurrent of pride and prejudice beneath "our" history

The third theme that emerged in PSTs' descriptions of the EAHOS related to its nature as "history." It is sometimes overlooked that HOS "seeks to explain the change, not merely to describe past techniques, theories, or books" (Sivin 1988, p. 45). Given this, reading EAHOS as a history and as something more than a simple collection of the past, becomes an important way to understand it and appreciate its values. From such a view, how we "tell" the story of science in East Asia becomes a central issue. Several issues raised by the PSTs in their reflections were pointed precisely at this problem of historiography, or "history writing", although this had never been explicitly brought up during the class. The starting point was to take EAHOS as "our" history (as opposed to Western HOS as "their" history), which made EAHOS special to them, as stated by S4:

> [EAHOS] is, in a sense, *our* story. It's not someone else's but ours, and we can look at history at the same time, and I could learn some context about why Korean science could not develop much, while I was preparing the presentation. That part was pretty interesting. (S4, interview, emphasis added)

Related to this point, several PSTs expressed concerns, and sometimes discomfort, about the implicit but normative "pride and prejudice" underlying the description of EAHOS. S4, for example, felt that the point of EAHOS was justification of what happened to East Asia in terms of science. To her, EAHOS in the modern era was trying to say that "there were good reasons that we could not achieve elaborate science," admitting the inferiority of East Asian science to modern Western science. Meanwhile, discussions about EAHOS in the pre-modern era tended to emphasize that "we *did* have some form of scientific knowledge", seemingly attempting to rebut the common belief that there was no science in East Asia. A feeling of the undercurrent of cultural pride and patriotism that runs through the telling of EAHOS was echoed by S2, who raised questions about examples in pre-modern Korean science. She found that, in many sources that she consulted during the course, EAHOS was described in a very value-laden manner and that many artifacts from pre-modern East Asia seemed not so much scientific as just original and artistic. When she learned about Cheugugi, the rain gauge invented during the Joseon dynasty in Korea, she suspected that other countries had also used cylindrical gauges to measure precipitation, and asked herself, "Is this really the science that our country had?" She expressed similar feelings about the story of the Bell of King Seongdeok (also known as the Emile Bell; see Fig. 1) in a high school textbook:

> In order to see whether the bells were really original and advanced, I think . . . we should know what bells were like in other countries, to be sure about where the Bell of King Seongdeok is placed among others and whether it's original. But I couldn't find any such information, so I wasn't sure [if it is really so or] I'm just being indoctrinated to believe so. (S2, interview)

When she was preparing her presentation on traditional science in Korea, she felt that the information came "so mixed with judgments." She felt that that part of the textbook was saying

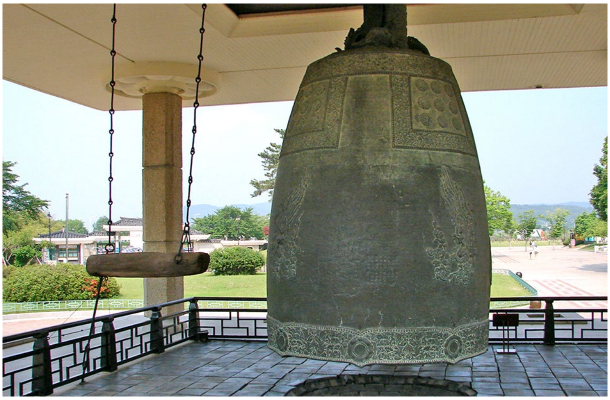

Fig. 1 The Bell of King Seongdeok (cast 771 AD) and the accompanying description in a high school textbook (Song et al. 2018): "The Bell of King Seongdeok, also called Emile Bell (cast in 771), is a masterpiece that resulted from bronze alloying and casting technology. The Buddhist bells of the Silla Dynasty are highly regarded for their deep and far-reaching sound, which is known to be the effect of a distinctive beat. The beautiful sound of Silla Buddhist bells comes from their unique features such as the cylindrical sound barrel attached to the dragon-shaped suspension loop at the top, the carved ground underneath the bell to enhance reverberation, and the high-quality metal produced by advanced alloying technology"

that "our ancestors did achieve a certain level of [scientific] work" to stress the excellence and novelty of traditional Korean science, but what was claimed to be scientific seemed rather a matter of aesthetics to her. In short, she kept questioning the way the textbook highlighted the value of Korean traditional science and could not avoid thinking that the historical account was not fair and impartial. These responses are particularly interesting when one recalls the more famous, persisting criticism that science curricula have created and perpetuated the supremacy of Western science over other forms of indigenous knowledge (Weaver 2018, p. 131); S2 was feeling that the same mistake was also made about non-Western sciences.

To better understand the PSTs' reactions above, it is helpful to consider the lingering criticism of the tendency among East Asian intellectuals to use the scientific achievements of the past to boost patriotism and collective self-esteem (Jeon 1966). Criticizing the "pride and prejudice" behind East Asian accounts of traditional science, Sung-Rae Park (1999) explains that as Koreans recognized the centrality of science and technology in modern society, they began to search for evidence of how Korean people contributed to the development of science and technology in the world (Park 1999). He goes on to interpret this tendency as a backlash against the Japanese colonial historiography that trivialized the value of Korean things, which made Korean intellectuals in colonial Korea (1910–1945) direct their attention to the "pride and joy" in the history of science in Korea as an expression of patriotism (Park 1999). This helps to explain the PSTs' reaction above as a manifestation of a deep-rooted problem in the historiography of science in East Asia, suggesting that teacher educators take a cautious approach in order to minimize such backlashes and prevent students from turning against their own past when introducing EAHOS.

Perceived relevance of EAHOS to science teaching

As we analyzed the perceived relevance of EAHOS, we noticed the existence of somewhat ambivalent attitudes about the value of EAHOS in science teaching. There was strong evidence supporting PSTs' general skepticism about the use of EAHOS in classrooms, but other portions of the data indicated that they did discover some important educational values in EAHOS. It seemed difficult to attribute such conflicting perceptions to individual differences because these conflicts were often observed within a single individual. Further examination of the data allowed us to conclude that this seeming contradiction was associated with how the PSTs viewed the nature of their roles as teachers, that is, whether the PSTs were interpreting the value of EAHOS specifically as science teachers or as teachers in general.

EAHOS for "science" lessons: Limited value compared to Western HOS

The PSTs commonly mentioned that the primary role of Western HOS in science teaching is to reveal the tentative and fallible nature of science, by showing students how a scientific theory does not persist but instead changes over time. On the contrary, with regard to EAHOS, they considered that it lacks the theoretical aspects of science that are crucial for being a history of "science" specifically. Understanding the relationship between HOS, NOS, and science teaching this way, they thought that EAHOS would have a little or limited contribution to science lessons, as in the following statements:

> When you read East Asian and Korean histories of science, there is not much content about physics, chemistry, and biology theories, so it would be difficult to use them in high school science lessons. (S1, reflective essay)
> The history of science in ancient East Asia and Korea is explained with a stronger focus on the inventions rather than the theories taught in school, so [its content] would not mean anything more than common knowledge. On the other hand, the history of science in modern East Asia and Korea is mostly no more than a process of learning about Western products of civilization. (S4, reflective essay)

Another frequent source of PSTs' reluctance seemed to stem from the fact that modern society and science curricula are based on Western science. They thought that, because we are living in the age of Western science, it is more natural to teach and learn about its history rather than EAHOS, which is disconnected from our lives:

> But I think students don't need to learn it [EAHOS] as deeply as Western HOS. Because [today's] society is formed based on contemporary science, it's right to learn the structure of contemporary science, and also it's true that the analytical method of Western science is very powerful. (S6, reflective essay)
> For sure, the current system of science relates more to Western HOS than to EAHOS. Given that historically Western people were more interested in surrounding objects and Eastern people were more into the selves and nature, this seems natural. So I see Western HOS as being more important than EAHOS in the discipline of science. (S8, reflective essay)

For these reasons, PSTs often felt that EAHOS is something more suitable to be addressed in social studies or history classes than in science classes. This indicates that the division of subjects in the school system can influence how they make sense of EAHOS and its place in the school curriculum. There was a strong indication that EAHOS does not fit very much into their own roles as science teachers when they mentioned other subjects:

> The content of EAHOS that we [studied] in the class, such as instruments like Cheomseongdae, calendars, sundials, and Cheugugi, could be learned in *history class* and is addressed in many history textbooks. (S3, reflective essay, emphasis added)
> I'm not saying that EAHOS is not [about] science, but in the current curriculum, it seems more natural to teach EAHOS in *social studies subjects* instead of science. (S8, reflective essay, emphasis added)

PSTs often mentioned the possibility of using the computational methods that were used by ancient and medieval Chinese people to deepen students' understanding of science. S1 said that we could use, for example, the methods for calculating the areas of shapes in *Nine Chapters on the Mathematical Art* (*Jiuzhang suanshu*) could be introduced to students because they provide a detailed and creative account and can prompt students' intellectual exercise. Such calculation methods were almost the only aspect of EAHOS that the PSTs found undoubtedly relevant to science teaching, possibly because these methods are fairly technical and so are compatible with modern science.

EAHOS beyond science: Broader educational benefits of EAHOS

Aside from the lack of relevance to "science teaching" specifically, the PSTs recognised several useful educational values in EAHOS. The first line of arguments concerned understanding of the nature of science by comparing EAHOS to Western HOS, particularly with regard to their contrasting worldviews. They thought that the pedagogical potential of EAHOS would be best realized by comparing it to Western HOS. S1 stated that although he thinks that "students need to know about East Asian and Korean history of science," unlike Western HOS, "[EAHOS is] meaningful when students learn them with other HOS." Later, he elaborated on this view:

> By learning Western HOS, we can understand the scientific revolution or theory change, so I think Western HOS is meaningful by itself. On the contrary, … [EAHOS is] centered on artifacts and technology, so it feels like an enumeration of information and lacks [theoretical] content, so if [students] only learn EAHOS, it would not do any more than raising a sense of pride such that "there was some technology in East Asia that superseded the West at some point." (S1, reflective essay)

Here, he takes a critical view on the "pride and prejudice" mentioned in the previous section and uses this to argue against teaching EAHOS alone. In his remark that followed, he presented what might make the comparison more meaningful:

> Yet, when [EAHOS] is viewed in juxtaposition with HOS in other civilizations including the West, we get to think about "Why was the scientific revolution possible in the West?" "Why did it not happen in Islam, India, East Asia, and Korea?" so I think it is very meaningful in this sense. Through this [experience], we can relate [HOS] with the social, cultural, and geographic backgrounds of each civilization and think about whether there were any scientific theories in each of them and the way each civilization viewed and thought about natural phenomena and objects. That is to say, I think we get to know better about what "science" is by comparing sciences in different civilizations. (S1, reflective essay)

Another major educational value related to the aspects of EAHOS as history. An example is S5′s statement, where he found the reason to teach EAHOS in "look[ing] back at the past and learn[ing]" so we can do better based on the success and failures of people in the past:

> For the Eastern history that connects the Korean peninsula and neighboring countries, [students] should know at least the outline if not the details. We should know the past to look back on the past and learn what people did well and improve and prevent what they did poorly. (S5, reflective essay)

Although S5′s comment reads as the benefit of studying "history" in general, such a view was repeated and made more concrete when S2 put a particular emphasis on the Korean history of science (as opposed to EAHOS in general) as a source of learning:

> I think students should at least know the Korean history of science above all. The reason we learn history is that it helps find correct ways to live through the study of the past. So I think, by learning the Korean history of science, we should teach ourselves how our country's science should develop in the future. (S2, reflective essay)

These two examples illustrate that both S5 and S2 developed some arguments for teaching EAHOS that certainly exceed what is commonly recognized as the aims of science education. Learning from the past is not something that the science curriculum usually set out as their goal but rather is one primary aim of the history curriculum. Moreover, there is no "our science" in science curricula; rather, it is something often deliberately erased when telling the story of science in schools. If we were to commit to the universal view of science education, it would be difficult to justify the inclusion of any content based on the fact that it was discovered in one's own country. Therefore, the PSTs were not limiting themselves to being the "science teachers" that they had defined but were talking as people beyond that role.

In interpreting EAHOS as history, a particularly interesting case was S4, who found more educational value in EAHOS than in Western HOS. She had little prior interest or knowledge in EAHOS before the course, and when she learned Western HOS, she felt that the content of Western HOS was like "tracing the historical development of [scientific] theories that we learn in textbooks," thus giving the impression that "there was not much new content; rather, it felt more like merely reviewing the theories one more time." She went on to say that when she was learning the histories of university-level science contents such as molecular orbital theory and other physics principles, it "didn't seem like addressing any deeper understanding about the theory than learning the fact that the theory had been generated" (S4, reflective essay). She also emphasized that Western HOS can be understood properly only when one has the relevant content knowledge. Contrary to Western HOS, she described EAHOS as an ideal subject to teach the aspects of NOS:

> If the aim of learning HOS is not to better understand scientific theories but rather to understand aspects of the nature of science, such as the fact that science cannot exist separately from society and that science is tentative, nothing is more suitable than EAHOS. Looking at modern Korean history together with the development of science [in modern Korea], students are able to understand what kind of science is required for each social circumstance and what progress is made as a result. (S4, reflective essay)

A clue to understanding such a reaction can be found in how she described her beliefs and thoughts about schooling in general. She had an open attitude toward the status of science and social studies in the school curriculum, which seemed to have made her more positive about the value of EAHOS. She said:

> My personal view is that it's not good for subjects to exist separately. Science and social studies are usually thought to be opposite subjects, but I want students to feel that, on the contrary, they are really closely related.… From that point of view, HOS is what we see from history in the future, so we can have multiple perspectives. (S4, interview)

Similarly, S7 also referred to the historical aspect of EAHOS by highlighting the value of history in guiding human civilization. While he mentioned that Western HOS is useful on its own because it teaches us about scientific revolutions and how theories change, he also thought comparing the two histories of science could provide us with valuable lessons:

> In high school science lessons, EAHOS could be used to show that science is influenced by socio-cultural backgrounds. Also, comparing Western HOS and EAHOS helps students understand what kinds of thoughts can develop society and science in what directions, so I think we need to teach both Western and East Asian HOS and [teach how to] compare and contrast. (S7, reflective essay)

In these quotes, we can observe that most of the values suggested by the PSTs did not directly relate to what they conceived as the "science" that is to be taught in science lessons. While they managed to find connections between their perceived aims for science education and Western HOS, the values that they found in EAHOS rather resemble the aims of history education, social studies education, citizenship education, and liberal education. These observations indicate that accepting the value of EAHOS in science lessons is connected to transcending the traditional concept of "science education" with a focus on a proper understanding of scientific content knowledge and methods. Figure 2 shows a schematic representation of the PSTs' ideas on the relevance of EAHOS to science teaching. In Fig. 2a, the filter (i.e., criteria for considering the relevance of EAHOS to science teaching) is stronger, but when they were thinking outside the subject boundary (Fig. 2b), it becomes more fluid, allowing the PSTs to find some aspects of EAHOS that would be

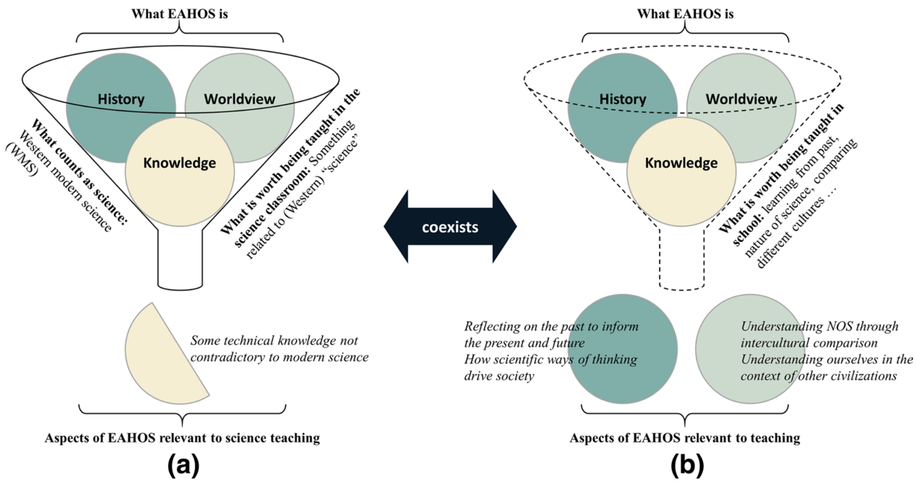

Fig. 2 PSTs' perceptions about the nature of EAHOS and its relevance to teaching

beneficial to students. These two modes of thought were mixed in the PSTs' responses and occurred simultaneously.

The PSTs did not find much use for EAHOS in relation to science teaching when they were thinking that students should be taught something related to Western and modern science (Fig. 2a). In this mode of thinking, they felt that most of what they learned about EAHOS is irrelevant to science teaching because it has little overlap with modern science and is too different from the rest of the science curriculum. The only aspects that were found to be potentially relevant were some technical knowledge, such as the traditional methods of calculation and measurement, which are still valid from a modern scientific view. However, when their roles as teachers were considered more broadly to encompass various aims that are not necessarily tied to Western science, some possible uses of EAHOS in classrooms were acknowledged, particularly in relation to its characteristics as history and worldview (Fig. 2b).

Despite such evidence of shifts in the PSTs' views, not all of them eventually developed positive perceptions about using EAHOS in science teaching. By the end of the semester, S3, a first-year PST, still felt that she did not understand the point of EAHOS, mostly because she was not even familiar with the history of East Asia in general. To her, EAHOS thus continued to be "some discrete pieces of knowledge about instruments, inventions, and methods of calculation." She mentioned that unless the learners have the content knowledge background necessary for understanding the history of it, EAHOS is likely to be "perceived as something separate from scientific theories" and can hardly "serve the aim of helping student's understanding." (S3, reflective essay)

Discussion

In this study, we investigated how Korean PSTs reacted to EAHOS as they learned and reflected on it in a undergraduate course. Having been educated as science students and science teachers, it turned out that they, for the most part, viewed the scientific knowledge in traditional East Asia from a stranger's view rather than taking it as something familiar to them. Yet the social, historical, and cultural contexts that surround East Asian science were felt more comfortable and meaningful to the PSTs. This resonates with Gandolfi's (2020b) argument that considering global history of science can promote learners' knowledge in social and cultural aspects of science. From a postcolonial view, experiences such as this can prompt critical reflection on the Eurocentric view of science created and perpetuated by the science curriculum and provide an opportunity to adapting science teaching to be culturally responsive (Medin and Bang 2014). Our findings indicated that the PSTs developed a range of ways to understand the nature of EAHOS and its relationship to science teaching. It should be noted that the course has stimulated the PSTs' reflection on diverse issues related to teaching science such as NOS, the value of history in science teaching, and what should be taught in science classrooms. These reflections were possible because PSTs had a chance to look at concepts of science and science education that they were familiar with from a critical point of view. S2′s critical evaluation of the Emile Bell reading and ideas for possible improvements provides evidence for such a benefit of the course.

Some of the values that the PSTs identified related to core components of liberal education and citizenship education, such as the capacity to view their own culture from an outsider's view, to empathize with people in other cultures or in the past (Nussbaum 1998), to draw lessons from past events, to consider different viewpoints on things to make fair decisions (Newton and Zeidler 2020), and to recognize the interconnected nature of science, society, politics, and culture (Erduran and Dagher 2014). However, most PSTs felt that these aspects are not as much relevant to "science" teaching as they are to social studies and humanities. If we were to accept these educational aims as something science teachers are also responsible for, teacher educators will need to encourage PSTs to develop broader self-conceptions as teachers.

In examining PSTs' perceptions of EAHOS, one common theme was that the PSTs were in a mixed position as a "science" teacher and an East Asian person simultaneously, where they experienced a tension between these two positionalities. As science teachers, they were "outsiders" to EAHOS, since the scientific knowledge and methods of East Asian people were different from what they had learned in schools and the university. As East Asian people, however, they managed to come up with diverse connections between what EAHOS represents and the cultural norms and codes with which they grew up. In other words, EAHOS was something familiar and foreign to them simultaneously. The familiarity was dominant in considering EAHOS as a worldview, where they easily accepted the value of EAHOS as an alternative worldview that their ancestors had taken for thousands of years. The foreignness was apparent when they were talking about the knowledge in EAHOS, which did not quite fit into the classificatory system of modern scientific knowledge and was oftentimes more practically than theoretically oriented. For the historical dimension of EAHOS, although the PSTs found it to be part of "our history," they also developed a critical viewpoint and recognized the hidden ethnonationalist ideology used to highlight the excellence (or at least offer an excuse for the inferiority) of "our science." (Park 1999).

More generally, we assert that such an experience, where PSTs are exposed to indigenous knowledge systems in their discipline, can provide a valuable opportunity to broaden their perceived roles as teachers. Future investigations informed by teacher identity research such as the works of Lucy Avraamidou (2014) and Jesper Sjöström (2018) may provide further insights on introducing non-Western HOS into science teacher education. Finally, we wish to underscore that such a benefit would not be limited within science education. Mathematics teachers could be introduced to how and for what purposes premodern East Asian people used mathematics, and social studies teachers could be given a chance to revisit historical thoughts on society in ancient and neo-Confucianist societies. Such experiences will not only contribute to decolonizing the curriculum but also broaden teachers' abilities for culturally responsive teaching (Medin and Bang 2014).

Although our findings provide initial insights on the potential of EAHOS in science teacher education, several methodological limitations of the study should be noted. First, due to the small number of study participants, a generalization of the findings could be made with caution. Second, EAHOS was only addressed for three weeks during the semester. Future research on the subject may benefit from investigating a larger group of learners with longer interventions. Third, it needs to be noted that PSTs' perceptions about EAHOS and its educational value (i.e., our research findings) are interrelated with the content, organization, and enactment of the course itself, due to the nature of the study as an action research project. For example, when PSTs described EAHOS as a collection of mere artifacts and tools, this could have simultaneously meant that the content of EAHOS in the course or course textbook was, to some extent, organized in such a manner. Also, the frequent discussions about the nature and roles of EAHOS in the class could have influenced PSTs' ways of thinking about them. This limitation, however, also informs teacher educators that if we want PSTs to recognize and appreciate the broader spectrum of possibilities that EAHOS offers, more attention is need in terms of how EAHOS is addressed in teacher education. In this light, our analysis provides some insights for introducing EAHOS to PSTs and potentially to students as well. For example, it seems an urgent task to develop a proper way of "telling" EAHOS, given that the present way based on artifacts and anecdotes clearly did not convince the PSTs. This is not to discount the pedagogical value of using artifacts—they are very useful for engaging learners with the lives of people in the past. However, if the aim was to be encouraging PSTs to explore diverse intersections between EAHOS and teaching, more ideas, worldviews, and comparisons with other scientific traditions and historiographical reflections should be considered for inclusion besides presenting individual artifacts.

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