Abstract  Catherine Milne’s book, *The Invention of Science*, recounts the history of science (mainly Eurocentric) from cross-cultural, historical and philosophical worldviews. Scientists, science educators, and teachers would find this an interesting book, not only for themselves but also for those with whom they interact. Most accounts are of the great men in science with some to women in science, including reference to the exclusion of women from science. Milne provides thought-provoking activities to use in the classroom, like asking students to write the processes that occur when sugar dissolves in hot tea, with students including the three components of causal explanation. She also encourages teachers to use narratives to help students learn the context of discovery in science. In a comparison of analogical, deductive, inductive and abductive reasoning, she encourages teachers to pay attention to dialogical arguments. Book review author predicts that Milne’s book will fit well with the nation’s next generation science standards, still in development form. Milne succeeded in her goal “to combine aspects of the philosophy and history; not just to focus on specific scientific ideas but to provide a hint of the complex relationship between place and history, space and time, in the development of Eurocentric science.”

Keywords  Science education · History of science · Nature of science · Worldview · Historiography

Catherine Milne’s new book, *The Invention of Science*, published by Sense Publishers (2011) provides an innovative approach for encouraging new ways to teach science education by examining the cross-cultural, historic and philosophical developments for scientific thought. Aimed particularly for science educators (including practicing K-12 science teachers, future K-12 teachers, science educators who teach future or practicing K-12 teachers, and college science professors), Milne’s book includes pertinent ideas for
those teachers who are thinking of ways to touch the lives of their students. The book has approximately 70,000 words in eight chapters.

The author, originally from Australia, earned two bachelor degrees from James Cook University, one in Education and the other in Chemistry/Botany. From Curtin University of Technology, she earned both a Master of Science degree and a Doctor of Philosophy degree in Science Education. I first met Dr. Milne as she was finishing her doctorate when I was visiting Curtin University in Western Australia. Once Milne graduated, she moved initially to the University of Wollongong in New South Wales, Australia for 2 years as the Coordinator of Tertiary Literacies (meaning she developed the general abilities and competencies of the university’s incoming undergraduates, using compulsory modules in computer, information, and statistical literacy), followed by a move to the United States where she became a Postdoctoral Fellow with Professor Ken Tobin. Initially, Milne was with Tobin at University of Pennsylvania and then at the Graduate Center of the City University of New York. Dr. Milne started her assistant professorship in the Department of Teaching and Learning at New York University in 2002, and she was promoted to Associate Professor and tenured in 2009.

I see Milne’s book as powerful method to enact the developing Common Core Standards for Science (CCSS)—a framework developed and initially published in draft form by the National Research Council (NRC 2010). Achieve is a collaborative group working with the NRC, the American Association for the Advancement of Science [AAAS], and the National Science Teachers Association [NSTA] to develop the next generation of science standards for the US and the assessments for those national standards (Achieve 2011), based on the framework being refined by the NRC. Milne places importance on the practices of scientists including asking good questions and on the models that scientists use to develop, test, and analyze their ideas. From my read of the draft CCSS framework, I think Milne’s book will fit well with the next generation science education standards.

Milne quotes from the currently existing National Science Education Standards (NRC 1996), which define science as “...a way of knowing that is characterized by empirical criteria, logical argument, and skeptical review... The goal of science is to understand the natural world” (p. 7). Milne then delves into the cross-cultural, historic, and philosophical connections and contexts for each of these above italicized words, thereby making learning their meanings much easier. She defines other words of interest in science, such as inductive argument, deductive argument, pluralist model and universal model similarly with their historical connections. Her definition of a dialectical argument as one “achieving truth through rational discussion,” is a critical part of science. Milne traces the cross-cultural, historic and philosophical developments for these terms and ideas, which are part of the knowledge traditions and current conception of science. Milne gets her audience to ponder more deeply how scientists conduct research, both in the laboratory and in the field, how science ought to be taught in K-12 and postsecondary settings, and simply the meaning of science to the general public.

Milne has activities for the teachers to use in their science classrooms. In one such activity, she provides nine statements for student-readers to consider and comment on science (modified from Galili & Hazan 2001). These statements are thought provoking in order to make students think deeply about the primary issues in the study of science. She encourages students to record and keep their responses and see if their responses change as they read the other chapters of her book. Another activity she includes is one in which students draw the relationship between Indigenous knowledge and Eurocentric science using both the pluralist model and the universal model. This approach of asking the readers to complete active exercises, helps the readers learn and remember the concepts more.
easily, especially if the readers discuss and compare their responses to other students in a science or science education classroom.

Milne also focuses on different forms of reasoning, including more on the dialectical argument and compares it to analogical reasoning, which uses more anecdotal evidence about a claim. She compares these to deductive, inductive and abductive reasoning, providing examples and activities of the types of reasoning, each with problems and benefits, to illustrate the differences. For instance, the creative thinking used in inductive scientific reasoning is necessary to move us beyond our present thinking.

The historical and philosophical roots and development of Eurocentric science are within the text but also in a handy timeline (including the time, place or person, and the development). This includes people not only about whom many readers have heard but also others, perhaps not known, from other countries, cultures, and parts of the world. For an activity Milne asks the students to include other developments in science that are not in her timeline table, because she is trying to get her readers to value and connect to their own knowledge. Milne also points to Aristotle’s classification scheme for knowledge, with theoretical knowledge as the highest form, followed by practical knowledge, and finally productive knowledge as the lowest form. Physics, the natural sciences, and mathematics are within Aristotle’s highest form, the theoretical knowledge. Aristotle’s hierarchy of knowledge downplayed the importance of some types of scientific knowing and discovery (like metallurgy) that were more practically based. Milne’s point is that these guiding philosophies of the day influence the types of scientific discoveries that come about (in part because of who is allowed to participate in science) and which types are heralded as important. Along with each scientist/philosopher Milne includes figures that capture their essence, making them more real than just names. Milne encourages students to engage in discussions to determine the type of reasoning(s) used in various examples provided.

Milne points to the worldviews of people who lived in earlier times and ways that religion was a powerful force in people’s worldview, defining worldview as “our culturally dependent fundamental beliefs about how the world works” (p. 57). Milne highlights worldview because she says, “Your worldview influences the questions that you ask and the way you understand your way of being in the world” (p. 188). Milne provides examples of this in a number of ways. For instance, Ptolemy’s world map first published in 150 CE in his Geographica, as reproduced in Milne’s book, is revealing of the worldview at that time. From Ptolemy’s time to around the fifteenth to sixteenth century when Eurocentric science started, explorers learned more about the Earth by exploration, the printing press allowed many to read by printing books and other materials, and other social changes led to the weakening of the philosophy of Greek Aristotle. Copernicus was one of the philosophers that ushered in the revolution of a heliocentric universe rather than Earth-centered in the sixteenth century. Ultimately, the Catholic Church put Copernicus’ book, On the Revolution of Celestial Spheres, on its forbidden list for four centuries because the book challenged the views of the church that the universe was centered about the Earth. In the early half of the seventeenth century the philosopher, Rene Descartes, was a proponent of the metaphor of the cosmos as a machine with scientific laws that control all things. Descartes saw humans as rational beings that could apply mathematics to decipher scientific laws. This mechanistic worldview was pushing out the Aristotelian worldview.

Milne introduces many important scientists, mainly men, and their contributions to the development of Eurocentric science. While Milne does point to women’s exclusion from Eurocentric science and professional societies, she might have included many more examples. Milne does cite Maria Sibylla Merian (who lived in the seventeenth to eighteenth century and studied insects), Margaret Cavendish (a theorist and natural
philosopher, who also lived in the seventeenth to eighteenth century), Marie Anne Lavoisier (who contributed with her husband, Antoine Lavoisier, in the discovery of oxygen and on an understanding of the concept of heat in the eighteenth century), the double Nobelist Marie Curie (who co-discovered radioactivity in the late nineteenth century and later purified radium, one of the elements she had discovered), Cecilia Payne-Gaposchkin (who in the early twentieth century proposed hydrogen and helium as the atmospheres of stars), and Nobelist Barbara McClintock (who determined the genetics of jumping genes in corn, in the mid-twentieth century). Two valuable books that I use in courses I have taught include one by Londa Schiebinger (1989) and the other by Margaret Wertheim (1997) in which the focus is on historical women in science.

Milne pushes student-readers to engage in critical thinking about science as well as scientific thinking. In an activity I found particularly useful, Milne asks readers to think of and to write the processes that occur when sugar dissolves in hot tea, with three components of causal explanation. The causal explanation or argument in science is an example of separate knowing associated with the development of Eurocentric science. But another type of knowing called connected knowing (as defined by Belenky, Clinchy, Goldberger, & Tarule 1986), associated with trying to understand each other’s position first in order to develop an understanding before explaining some point, can also be used and is more associated with women’s ways of knowing. Milne encourages her teacher-readers to become aware of both types of explanations as both types of knowing have value in helping their students learn. Milne provides a handy table that differentiates ‘connected knowing’ from ‘separate knowing’ with respect to the following aspects: goal, relationships between knowers, relationship between knower and what is known, emotions, ontology, authority (epistemology), and genre. Milne makes a parallel between the importance of the teacher becoming aware of students’ prior knowledge, which may come in the form of stories told by the students, and the connected knowing. If the teacher listens to her students’ stories, she will come to understand her students, which will help her present the scientific ideas in a way that helps the students connect to their prior knowledge.

Pointing to Wiggins and McTighe book (1998), Understanding by Design, Milne delves into, and explains, the importance of three of Wiggins and McTighe’s six facets of understanding that are part of connected knowing, which include: interpreting, empathizing, and having self-knowledge. Scientific inquiry involves scientists having prior knowledge of the system and the theories under study, so they know the appropriate questions to ask—often scientists have empathy or a feeling for the organism (as stated by Evelyn Fox Keller (1983), about Barbara McClintock), so connected knowing would encourage empathizing needed for understanding.

Finally, Milne examines the development of the language, defined by Milne as “central for all forms of knowledge” (p. 14), for communicating science among scientists in Eurocentric science. Bacon and followers encouraged the use of simple, compact English without flowery descriptions, but they also developed nominalizations of verbs into nouns (like refract into refraction, and move into motion) and adjectives into nouns (like pure into purification). The advantage of a nominalization is that you do not need to indicate the time, place, process or person. Nominalizations became part of the scientific discourse because they are efficient, but nominalizations make reading of science more difficult for the inexperienced person because they condense prior knowledge, making the meanings more obscure. Therefore, a teacher becoming aware of nominalizations might well help address her students’ lack of understanding of science. Milne provides activities that help the reader learn to identify nominalizations. Scientists tend to use nominalizations to move
the arguments towards the theoretical, and Newton was a great example of such a scientist. Milne’s advice to the science teacher is to present “the language of science as a vibrant, evolving aspect of scientific endeavor, and not something that is fixed and unchanging” (p. 178). Though Milne highlights potential pitfalls of using narratives in science teaching, such as a particular narrative from a textbook concerning Antoine and Marie Anne Lavoisier on the development of the concept of heat, Milne also delves into narrative’s potential advantages, such as a narrative she provides in cartoon form about different historic ideas on the source of embryos. Milne encourages teachers to carefully use narratives in their classrooms in their teaching and learning of the history of science, as people are more accustomed to learning from narrative in other parts of their lives.

In my opinion, Milne succeeded in her goal “to combine aspects of the philosophy and history; not just to focus on specific scientific ideas but to provide a hint of the complex relationship between place and history, space and time, in the development of Eurocentric science” (p. 191). Science teachers, science educators and college science professors could all find plenty of insightful ideas and engaging activities in Milne’s book to incorporate into their own classrooms in order improve their students’ environment for learning science.

References


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Penny J. Gilmer currently, is a professor emerita in chemistry and biochemistry from Florida State University where she taught chemistry and biochemistry; science, technology and society; and women in science, for 33 years. Her education included a bachelor’s degree in chemistry, a master’s degree in organic chemistry, a doctorate in biochemistry, and near the end of her career, a second doctorate in science education. She has authored one book, co-authored two books, co-edited one book and one monographs. She is currently finishing a co-edited book commemorating 100 years since Marie Curie’s Nobel Prize in Chemistry. She is a past president of the National Association for Research in Science Teaching.