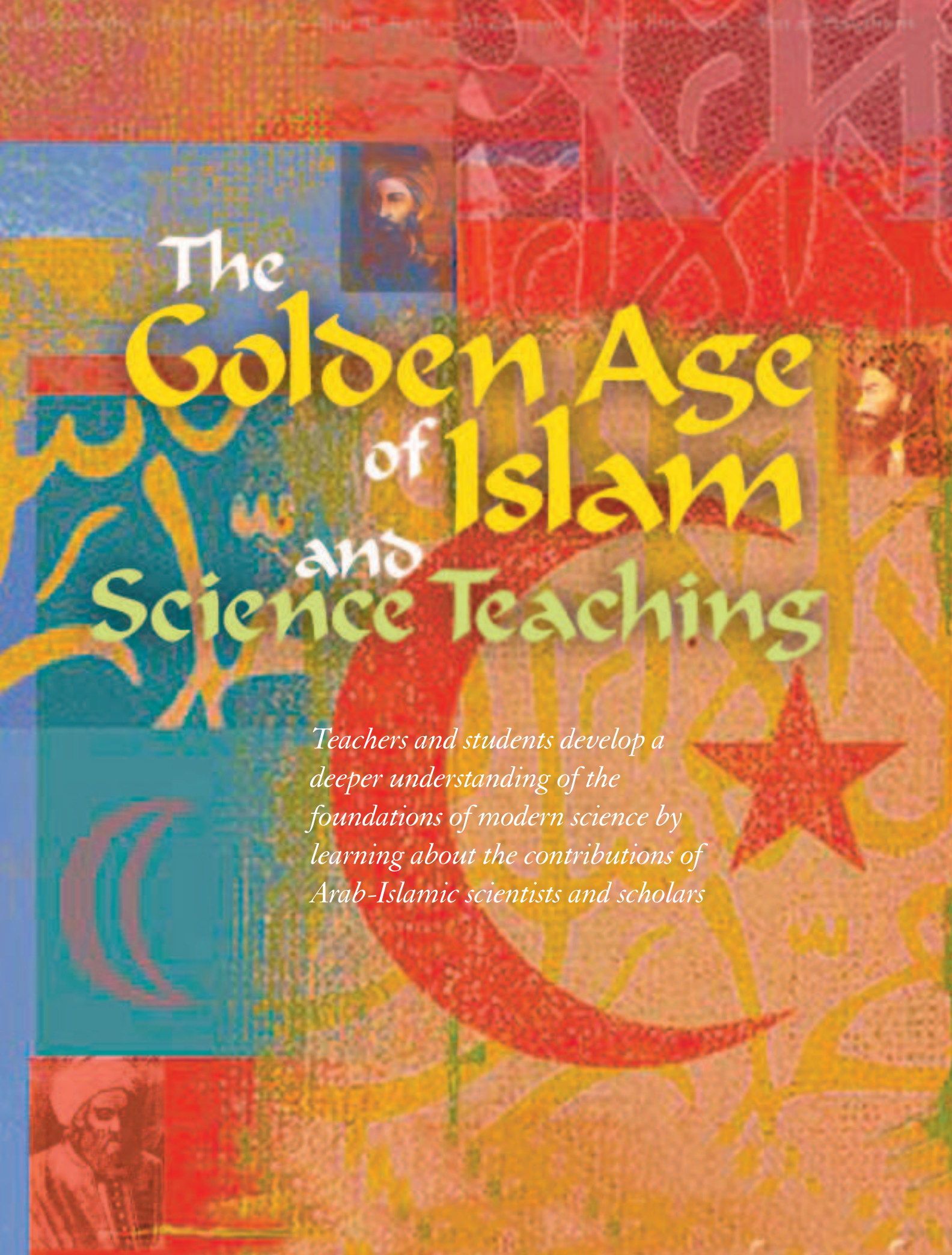
The Golden Age of Islam and Science Teaching
Teachers and students develop a deeper understanding of the foundations of modern science by learning about the contributions of Arab-Islamic scientists and scholars

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The National Science Education Standards point out that "many individuals have contributed to the tradition of science and that, in historical perspective, science has been practiced in many different cultures" (NRC 1996, p. 21). Additionally, the Standards recognize that students could greatly benefit from learning the relationship of science to mathematics and to technology. McComas (2004) states that as part of the human domain, science itself is greatly influenced by social, economic, and cultural factors. Kuhn, in his classic work, *The Structure of Scientific Revolutions* (1996), further argues that science and scientific research have to be understood as human activities reflective of the era, culture, and scientific community in which they were developed.

Helping teachers, preservice teachers, and students develop a sense of the nature of science in the classroom is a necessary part of encouraging scientific literacy and inquiry (Abd-El-Khalick 2001; Abd-El-Khalick and Lederman 2000; Bell, Lederman, and Abd-El-Khalick 2000; Clough and Olson 2004; Lederman, Wade, and Bell 1998; McComas 2004). This article itself cannot do enough justice to the immense cultural and scientific wealth of the Golden Age of Islam, a period that lasted roughly from the eighth century through the fourteenth century, CE. The purpose of this article is to highlight the many Arabic-Islamic scientific contributions to modern science and the need to study the achievements of other cultures in general. Because modern views of the origins of Western science often is taught divorced from this history (Teresi 2002), a serious study of this period is essential, appropriate, and rewarding for science teachers.

Scientists move eastward

The demand for science in Western Europe between the fifth and ninth centuries was reduced drastically under feudalism. Science, culture, and even literacy, by in large, were confined to the clergy (Bernal 1983). Scientific thought in the Byzantine Empire fared no better. With the repression of free inquiry, exemplified by the closing of the School of Athens in 529 CE and religious prosecutions, especially of the Nestorians and Monophysites, scholars and scientists fled east to the more cosmopolitan and tolerant Arabic-Islamic lands. There, they were to become the organic links between ancient Greek sciences and the Arabic-Islamic sciences that were beginning to flourish, especially in the new cultural metropolis of Baghdad (Boyer and Merzbach 1989; Goldstein 1980).

Within a few years of the death of Mohammed in 64 CE, his followers had decisively defeated both the Roman and Persian armies. By the eighth century, the Islamic empire stretched from India and Persia, to Morocco and Spain, from the Ganges to the Atlantic Ocean, including Egypt and large parts of the Byzantine and Roman Empires along the Mediterranean. This vast area was united under a common religion, culture, and literary language.

Owning to the intellectual thirst, open-mindedness, and vigor at the peak of this era, the knowledge and wisdoms produced by the ancient cultures of these lands—including the Babylonian, Hindu, Egyptian, Phoenician, and Greco-Hellenistic cultures—were brought together, preserved, and cultivated (Boyer and Merzbach 1989; Eves 1990; Goldstein 1980; King 1997; Teresi 2002). The language primarily used was Arabic, but these scientists included not only Arabs, but also Indians, Persians, Christians, and Jews, as well as Muslims from the areas around Cordoba and Granada in Spain. Many caliphs, especially in Damascus and Baghdad, became patrons of learning and invited distinguished scholars to their courts. If not for the effort of the potpourri of scholars and scientists at the employment of these caliphs, much of the work of these cultures would have been irretrievably lost in Europe over the long period of the Dark Ages. The immediate effect was a great stimulus to culture and science—the Golden Age of Islam. During its height, in virtually every area, the work of Arabic scientists was the most advanced in the world (Huff 2003).

Mathematics

Two broad currents of ancient mathematical thought were brought together in Baghdad, fused into a coherent whole, developed, and passed on to the future as the basis for mathematics in which scientists still operate today: The Greek, with its emphasis on geometry and trigonometry, and that from Babylon and India, which centered on calculations and numerical symbols (Goldstein 1980). The earliest known written Arabic treatise on the Hindu-Arabic system (consisting of nine symbols and a zero) is by Al-Khwarizmi around 830 CE. He is one of the greatest mathematicians of his time, whose writings on algebra (a term derived from an operation used to solve the quadratic equation called *al-jabr*) and decimal arithmetic were so widely influential in the West, that they later named after him one of their early names for arithmetic, the *algorism* or *algorithm* (Boyer and Merzbach 1989; Smith 1997).

Astronomy

In science, no other field was connected to mathematics as intimately as astronomy. The Arabic-Islamic influence on the development of this branch of science can be recognized today—many stars such as Vega and Rigel are still known by their Arabic names, as is Ptolemy's great work, the *Almagest*. In a particularly interesting example, proposed planetary models by Ibn al-Shatir in the 14th

In the classroom: Integrating cultural contributions into science teaching.

Spanish, history, or social studies teachers often have "flag days" or "international days" to celebrate cultural diversity and expose and inform students to other cultures and their contributions. To better understand the nature and history of science, students would greatly benefit by similar flag days or international days in the science classroom. Either as part of summarizing a particular topic or a year's work, students in teams can investigate science history, make presentations, construct fairs, or put together festivities where research can be presented. Projects could include methods of time keeping and calendars used at different times and in different parts of the world, or developments and contributions pertaining to entire branches of science, such as biology and chemistry.

These projects could also be supplemented with discussions of why some models, especially the ones we today consider wrong such as the geocentric, would be accepted, rejected, or face great resistance before being adapted or revised. Festivities and projects can be further integrated with history or social studies courses, and spiced up with music, art, food, and delicacies native to these cultures.

century were mathematically identical to those of Copernicus some 150 years later. The big difference was that Ibn al-Shatir developed the models while trying to improve the geocentric system whereas Copernicus proposed a heliocentric one (King 1997). Copernicus' own work incorporated mathematics suspiciously identical to that found in al-Shatir's work (Boyer and Merzbach 1989; Teresi 2002). The work of Al-Shatir and other Islamic mathematicians and astronomers must surely have influenced the work of Copernicus.

Health and medicine

Health and hygiene played an integral role in the Islamic way of life, and some of the most famous Arabic-Islamic contributions were in the field of medicine. Abu Al-Razi (ca. 864–ca. 932) known to the West as Rhazes, was born in Persia and was the author of more than 140 books. His greatest medical work was the "Al Hawi," the *Continens*, an encyclopedia of medicine and surgery—a summary of all branches of the subject composed of 24 volumes. Another was Al-Zahrawi (ca. 936–ca. 1013) or Abulcasis. Born near Cordoba, Spain, Al-Zahrawi was one of the Muslim scientists who laid the foundations of modern surgery in the West. His three books on the subject remained standard textbooks for nearly a thousand years. The most famous textbook was the *Manual for Medical Practitioners,* which contained 278 drawings of the equipment used for surgery (Al-Said 1997). A third great physician was Abu Ibn-Sina (ca. 980–ca. 1037) or Avicenna, one of the greatest scholars of the Islamic Golden Age. He wrote 250 works of different lengths, the best-known being *The Law of Medicine*, otherwise known as the *Canon* (a medical encyclopedia of Greek and Islamic medical knowledge that covers medicine, anatomy, physiology, pathology, and pharmacology). Once the book was translated into Latin, it became one of the most frequently printed scientific texts during the European Renaissance. Along with the Al Hawi it was taught in Western universities for centuries (Al-Said 1997; Goldstein 1980).

Optics

When it came to transforming an entire discipline, the field that experienced the most Arabic-Islamic influence was optics. Optics was expanded from the Greek focus on vision, *optiḳa*, to a study of light lenses and mirrors, as well as of the eye itself. Its methodology went beyond the geometric and into the experimental realm. Ibn al-Haytham's (also known as Alhazen, ca. 11th century CE) seven books on the topic included a wide range of subjects: the properties of light and color, visual perception and visual illusions, and reflection and refraction. His most celebrated book, *Kitab al-Manazir*, was translated into Latin in the late 12th century and then into Italian. Not only did the book have a deep impact on late medieval science, but it also influenced Renaissance artists, and the study of light all the way to the 17th century; Leonardo da Vinci was one of his particular admirers (Goldstein 1980). The notion of experiment was adopted by Ibn al-Haytham from astronomical works, and he used it to replace purely geometrical demonstrations. Given the dominance of Aristotelian beliefs that considered physical experimentation to be unworthy manual labor, this was an important development in the transformation of this science, though Ibn al-Haytham would continue to regard experiments in optics as mathematical inquiry (Kheirandish 1997).

Chemistry

Arabic-Islamic scientists made some of their greatest original contributions to modern science in the field of chemistry. Their work was deeply rooted in the ancient civilizations, both mystical and experimental, and in many ways led to the founding of modern, scientific chemistry. Here again, free from the class prejudices that had kept the Greeks from integrating manual experiments with their thinking, Arabic-Islamic scientists developed the first full-scale production of such commodities as soda, alum, nitre, and other salts, particularly used then by the textile industry (Bernal 1983). Not only was the knowledge of advancements in chemistry and an extensive coverage of

chemical substances used by physicians passed on to the West, but so too were the tools and techniques.

Arabic-Islamic knowledge and the West

The victory of the Spaniards over the Moors coincided with the reawakening of scientific thought in Europe. Spain (and, to a lesser extent, Sicily), with its rich Moor culture, was to be a window into the cultural heritage of Islam. Among the translations from the Arabic were Avicenna's *Canon*, al-Razi's *Liber Almansoris,* Ptolemy's *Almagest*, Euclid's *Elements*, and the core of Aristotle's scientific writings. Gerard of Cremona in particular is credited with the translation of more than 70 works, including many of the aft mentioned, after his arrival in Toledo in 1160 CE (Goldstein 1980).

Developing a sense of science

While a brilliant cultural development was taking place during the Golden Age of Islam, most of Europe had fallen into decay after the collapse of the Roman Empire. As Bernal in his four volume monumental work *Science in History* (1983) points out, much more than the transmission of Greek science, the direct transmission of the huge collection of stored knowledge of Arabic-Islamic science, data, experiments, theories, and methods gave the sciences of feudal Christendom a huge impetus out of the Dark Ages. While Arabic-Islamic science ultimately declined during the 14th century, it nonetheless provided modern science with an organic continuity through the ages.

Studying the history of science helps students develop a sense of science (and mathematics) as a dynamic, human enterprise, and also provides a better understanding of "the role that science has played in the development of various cultures" (NRC 1996, p. 107). It also shows students "how difficult it was for scientific innovations to break through the accepted ideas of their time to reach the conclusions we currently take for granted" (NRC 1996, p. 171). By coming to appreciate the immense contributions of Arab-Islamic scientists and scholars, students develop a deeper understanding of the foundations of modern science. ■

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Editor's note

For a review of Teresi's book, visit NSTA Recommends at *www2.nsta.org/recommends/product.asp?id=14597.*

References

Abd-El-Khalick, F. 2001. Embedding nature of science instruction in preservice elementary science courses. *Journal of Science Teacher Education* 12(3): 215–233.

Abd-El-Khalick, F., and N.G. Lederman. 2000. The influence of history of science courses on students' views of nature of science. *Journal of Research in Science Teaching* 37(10): 1057–1095.

Al-Said, M.S. 1997. Medicine in Islam. In *Encyclopaedia of the history of science, technology, and medicine in non-western cultures*, ed. H. Selin, 695–698. Dordrecht, The Netherlands: Kluwer Academic.

Bell, R.L., N.G. Lederman, and F. Abd-El-Khalick. 2000. Developing and acting upon one's conception of the nature of science: A follow-up study. *Journal of Research in Science Teaching* 37(6): 563–581.

Bernal, J.D. 1983. *Science in history*. 3rd ed. Cambridge, MA: The MIT Press.

Boyer, C.B., and U.C. Merzbach. 1989. *A history of mathematics*. 2nd ed. New York: Wiley.

Bryan, L.A., and M.M. Atwater. 2002. Teacher beliefs and cultural models: A challenge for science teacher preparation programs. *Science Education* 86(6): 821–839.

Clough, M.P., and J.K. Olson. 2004. The nature of science: Always part of the science story. *The Science Teacher* 71(9): 28–31.

Eves, H. 1990. *An introduction to the history of mathematics*. Orlando, FL: Saunders College Publishing.

Goldstein, T. 1980. *Dawn of modern science: From the Arabs to Leonardo da Vinci*. Boston: Houghton Mifflin.

Huff, T.E. 2003. *The rise of early modern science: Islam, China, and the West*. 2nd ed. New York: Cambridge University Press.

Kheirandish, E. 1997. Optics in the Islamic world. In *Encyclopaedia of the history of science, technology, and medicine in non-western cultures*, ed. H. Selin, 1117. Dordrecht, The Netherlands: Kluwer Academic.

King, D.A. 1997. Astronomy in the Islamic world. In *Encyclopaedia of the history of science, technology, and medicine in non-western cultures*, ed. H. Selin, 125–133. Dordrecht, The Netherlands: Kluwer Academic.

Kuhn, T.S. 1996. *The structure of scientific revolutions.* 3rd ed. Chicago, IL: University of Chicago Press.

Lederman, N.G., P.D. Wade, and R. Bell. 1998. Assessing the nature of science: What is the nature of our assessment? *Science & Education* 7:595–615.

McComas, W.F. 2004. Keys to teaching the nature of science: Focusing on NOS in the science classroom. *The Science Teacher* 71(9): 24–27.

National Research Council (NRC). 1996. *The national science education standards*. Washington, D.C: National Academy Press.

Smith, J.A. 1997. Arithmetic in Islamic mathematics. In *Encyclopaedia of the history of science, technology, and medicine in non-western cultures*, ed. H. Selin, 68–70. Dordrecht, The Netherlands: Kluwer Academic.

Teresi, D. 2002. *Lost discoveries: the ancient roots of modern science—from the Babylonians to the Maya*. London: Simon & Schuster.