A Review of Innovations in MSE Education: From Wulff to Web

L. Vanasupa and K.C. Chen

While the first tools for teaching materials science and engineering (MSE)—which developed as a profession during the post-World War II period—consisted of textbooks such as *The Wulff Series* and programmed courses in the mid-1960s, in the last decade, we have seen a virtual explosion in the area of innovations in MSE education. The innovations that we review in this article can be categorized as either teaching–learning aids or classroom–laboratory techniques.

Teaching–Learning Aids: "Toys" that Teach

For the K–12 audience, R.P.H. Chang and M. Hsu of Northwestern University have created the Materials World Modules (see *MRS Bulletin*, March 2000), with the aim of increasing the technical literacy of materials and improving math and science education. The module activities are hands-on and project-based, while centering on everyday objects. Tse et al. at Cornell University use the web to introduce MSE as a career choice to high-school students and first-year university students. The site is designed around identifiable, everyday items, such as an acoustic guitar. Here, the student can see short video clips that demonstrate MSE in products. In addition, The Minerals, Metals and Materials Society (TMS) has also developed a website that showcases MSE as a career.

In the university setting, interactive CD-ROMs are now accompanying student textbooks as personal computers are becoming more commonplace. One CD by C.J. McMahon, Jr. provides a glossary that can serve as a reference. The user selects specific concepts, organized in an alphabetical fashion, and views text alongside animations and video clips. The organization of the CD-ROM by J.C. Russ follows his text, yet allows the student to explore other concepts of interest. A group from the United Kingdom has developed the Materials MATTER Series, which largely serves as a text, although accompanied by a manual. Concepts such as electron transitions between valence band and conduction bands in semiconductors are demonstrated on the CD-ROM through animations. One of the strengths of the MATTER Series is the interactive homework-type problems that allow students to test their understanding of the material with instant feedback. J. Schaffer et al. also have an accompanying CD-ROM for their textbook that includes some animation and a phase diagram tutorial. The CD-ROM by W. Callister contains exercises on crystallographic directions and planes, animations of different crystal structures, dislocation movements, simulated tensile tests, and a database of material properties.

K.P. Constant of Iowa State University has developed a CD-ROM (soon to be commercially available) that takes a slightly different approach. Her emphasis is on the relationships between processing and properties. The program allows the user to input processing parameters and perform virtual experiments on materials. The program provides a simple but elegant simulation tool for materials processing. M. DeGraef of Carnegie Mellon University has also created a simulation tool. The student defines a crystal composition and structure, and then simulates x-ray diffraction patterns. The program

Innovations in MSE Education Resource

Teaching–Learning Tools

K–12

- Materials World Modules (Northwestern University) http://mrcemis.ms.nwu.edu/mwm/
- Materials by Design (Cornell University) www.mse.cornell.edu/engri111/
- Career Resource Center for Materials Science & Engineering (The Minerals, Metals & Materials Society [TMS]) http://www.crc4mse.org/

University

CD-ROMs as stand-alone or that accompany textbooks:

- W. Callister, *Materials Science and Engineering: An Introduction* (John Wiley & Sons, New York, 2000)
- K.P. Constant, *CD on Materials Processing* to be published by Brooks/Cole Publishers, Pacific Grove, California; see website www.brookscole.com.
- J.A. Jacobs, *Experiments in Materials Science* (Prentice-Hall, Old Tappan, NJ, 1998)
- *Materials Science on CD-ROM: An Interactive Learning Tool for Students* (PWS Publishing, Chapman & Hall, New York, 1996). Now available from Liverpool University Press, Senate House Abercromby Square, Liverpool, L69 3BX, UK; e-mail robblo@liv.ac.uk.
- C.J. McMahon, Jr., *Interactive Glossary for Materials Science and Engineering* (Merion Media, Lebanon, NH, 1996)
- J.C. Russ, *Materials Science: A Multimedia Approach* (PWS Publishing, Boston, 1996)
- J. Schaffer, *The Science and Design of Engineering Materials* (McGraw-Hill, New York, 1999)

Web sites:

- M. deGraef (Carnegie Mellon University) Point Groups and Bravais Lattices: http://neon.mems.cmu.edu/degraef/pg/index.html
  2D X-Ray Crystallography Simulator: http://neon.mems.cmu.edu/degraef/xray/index.html
  3D X-Ray Diffraction Simulator: http://neon.mems.cmu.edu/degraef/xr3D/xr3D.html
- T.P. Weihs (Johns Hopkins University) Demobase: http://ntwww.hcf.jhu.edu/matsci
- University of Michigan, MSE Department Materials Education Library: http://msewww2.engin.umich.edu:591/default.html

Games:

- *Fab Line*™: The Integrated Circuit Fabrication Game (Zzotto Enterprises; www.zzotto.com)

Classroom–Laboratory Techniques

Preparation for the "Real World":

- C. Baillie, R. Grimes, in *Proc. Annual Conf. 1998* [CD-ROM] (American Society for Engineering Education, Washington, D.C.) Paper 00435.
- C. Demetry and J.E. Groccia, *J. Engineering Education* **86** (1997) p. 203.
- R.W. Heckel, J. Pilling, and M.R. Plichta, in *Proc. Annual Conf. 1995* (American Society for Engineering Education, Anaheim, California, 1995) p. 982.
- A.J. Muscat, E.L. Allen, D.H. Green, and L.S. Vanasupa, in *Proc. Annual Conf. 1998* [CD-ROM] (American Society for Engineering Education, Washington, D.C.) Paper 01025.

Multimedia Devices:

- Web site: msewww.engin.umich.edu/frameset.html

To learn more about a number of these projects, see the *Journal of Materials Education* **18** (1,2) (1996); **19** (1,2) (1997); **20** (1,2) (1998); and **21** (1,2) (1999).

also assists students in understanding 2D Bravais lattices.

For "nonvirtual" experiments, J. Jacobs of Norfolk State University has compiled the past 10 years of the National Educator's Workshop, and the CD-ROM includes over 200 experiments and demonstrations of materials technology. In addition, T.P. Weihs of Johns Hopkins University has assembled about 40 demonstrations for the MSE classroom. The website contains a description of the demonstration, video clips, and instructions on implementation. The MSE Department at the University of Michigan also has a website to access demonstrations.

Specific to semiconductor processing courses, *Fab Line*™ is an integrated circuit (IC) fabrication board game developed by R. Pinizzotto. This game submerges the student into the IC industry with all the perils of real-life manufacturing. The board-game venue gives students a chance to apply their learning in a fun format.

Classroom–Laboratory Techniques: New Tricks for Dogs of All Ages

Several innovative techniques have been conceived to address particular challenges to MSE educators. A common task for many MSE departments (which are typically small) is teaching a MSE "service course" to a large number of engineering students of diverse disciplines. Creating and maintaining high interest levels in courses are also goals of most instructors, and preparation for the "real world" is becoming more widely demanded from students and employers alike.

An approach developed by C. Demetry and J.E. Groccia of Worcester Polytechnic Institute replaces some of the traditional lecture format with an "active" format, by introducing a "product dissection project" and Peer Learning Assistants. The teacher serves as the "manager" to student teams, and cooperative learning methods and exercises are incorporated to build teamwork and communication abilities. Students taught within this modified format have been found to retain more knowledge than in traditional course offerings. C.A. Baillie and R.W. Grimes of the Imperial College (United Kingdom) use a format that makes use of peer tutoring. During weekend retreats, the peer tutors are trained to question students in a manner in which answers are arrived through their own reasoning. The goal is to reach a greater number of students than is possible by a sole instructor.

The faculty at the University of Michigan MSE Department addresses the problem of declining enrollments in the MSE introductory course by utilizing multimedia devices. A website has been created for the course, and is geared toward the post-generation-X-ers with pop culture woven throughout. The students view video clips of demonstrations and references to MSE challenges in sports equipment. In addition, the classroom (typically ~100 students) is made interactive with hand-held electronic devices that record each student's answer to the instructor's questions. The answers are compiled in real-time and the statistics of the answers are displayed on a screen.

J.B. Hudson and M.A. Palmer also make use of computer media in their studio classroom (Renssalaer Polytechnic Institute), but with a different approach. Students work in groups of three to four at computer stations to conduct virtual experiments in chemistry and materials. A typical class meeting lasts two hours and consists of a series of 10–20-minute lectures followed by a 20-minute activity.

Responding to requests for "real-world" knowledge, some instructors have experimented with formats that mimic industrial experiences. At Michigan Technological University, R.W. Heckel, J.E. Pilling, and M.P. Plichta created a one-year senior-level course that requires students to work in teams with a faculty member and an industrial associate. Each team is given a charge to solve a current industrial problem, such as the analysis of factors critical to vapor phase deposition of TiN on plastics. The fall quarter is devoted to instruction on the design process and teamwork skills, while the remainder of the year is spent working as an industrial team. E.L. Allen, E.D.H. Greene, and A.J. Muscat at San Jose State University pioneered the "Start-Up Company" format. Their course on semiconductor processing is run as if the students are part of a small start-up company. A group of 8–12 students forms a "company," with half of the students working on manufacturing the product and the other half improving the process. The course is carefully structured, making use of active and cooperative learning techniques such that students have opportunity to develop skills of experimental design, teamwork, communication, and open-ended problem solving. E.L. Allen et al. create the start-up company environment by using "Company Documents" rather than a laboratory manual, and give incentives through "patents" and a product "traveler" (a document used in industry to keep track of the product).

All sorts of innovations in MSE education have taken place over the past decade. Those who want to learn more may consider attending the 2000 Materials Research Society Spring Symposium on MSE Education in April or the Gordon Conference on MSE Education this summer. Also, the MSE Education Forum at www2.tms.org:900 contains links to the MSE education efforts of various professional societies; see sidebar for a list of resources.

Education Exchange highlights experiences of scientists and engineers with local schools (K–12), community programs, and university programs, along with helpful hints and resources. If you would like to share your own involvement in science education, contact *MRS Bulletin*, Materials Research Society, 506 Keystone Drive, Warrendale, PA 15086-7573 USA; fax 724-779-8313; e-mail Bulletin@mrs.org.

Linda Vanasupa *is a professor in the Materials Engineering Department at the California Polytechnic State University. She received her MS (1987) and PhD (1991) degrees in materials science and engineering at Stanford University.*

Katherine C. Chen *is an assistant professor at California Polytechnic State University. Her doctorate is from the Massachusetts Institute of Technology (1996) in materials science. She has a BS degree in materials science and engineering and a BA degree in chemistry from Michigan State (1990).*