

Lessons for Practice

Instructional Design Strategies from Engineering Education

Kathy J. Schmidt

Due to a number of challenges, such as the emergence of a global economy, changing student demographics, current science on how people learn, low numbers of engineering graduates, and improved instructional technologies, engineering education is under scrutiny across the country. In the United States, only 5% of under-



Kathy J. Schmidt, Director, Faculty Innovation Center, 1 University Station, C2200, College of Engineering, The University of Texas, Austin, TX 78712. Telephone: (512) 232-1536. E-mail: k.schmidt@mail.utexas.edu Web: <http://fic.engr.utexas.edu>

graduates earn engineering degrees. Conversely, China's current group of engineering undergraduates represents 40% of all graduates. Is this a trend we can positively address by enhancing our engineering education practices, or do we need to find ways to reach potential students with alternative delivery methods such as distance learning? Even if we do increase our numbers of graduates, will the marketplace be ready for them? While there are numerous efforts underway to help prepare students in the lower grades for the pipeline into higher education in engineering, science, or technology, I will address two of the challenges mentioned above (science of learning and instructional technologies) and how they can influence change in engineering education.

Why should the United States Distance Learning Association and its members have interest in specifics about engineering education? Are there parallels to be drawn from a discipline-specific approach, or are there instructional issues relevant across the disciplines that are applicable to distance learning pro-

fessionals? While there are "signature pedagogies" used to deliver engineering instruction (Schulman, 2005), engineering professors who employ instructional design strategies and base classroom activities on student outcomes are following the basic tenets of quality instruction. This commentary will not delve into specifics of engineering instruction such as design or laboratory classes, but will instead look at how the science of learning and instructional technologies are influencing engineering education practices.

Although engineering is a scientific discipline that is built on the study of scientific principles and methodology, it is really driven by the application of science to address the needs of society. This practical approach to knowledge can be seen in how engineering professors want to assess change in their classes and because they are theory-based thinkers; they review the scientific findings on pedagogy before they incorporate such practices into their teaching. Given that engineers use a systems approach, they are at least open to instruc-

tional design and a systematic approach to instruction. The use of a systematic approach to instruction provides a framework to analyze course components and methodology as well as the ability to complement pedagogical practice with technological capabilities.

Many view an engineering class as one in which a professor lectures (a chalk talk) and works derivations on the board while students dutifully take notes. This type of engineering class does exist, but take a look at the *Journal of Engineering Education* to see what trends and empirical evidence exist that promote more active learning environments. Colleges of engineering across the nation now support their own engineering teaching centers where learning scientists, instructional designers, and media specialists are readily available to help create instruction that meet the needs of today's students.

Many of these centers promote pedagogy based on the National Academy of Sciences book *How People Learn* (HPL) (Bransford, Brown, & Cocking, 2000) and its practical findings. Often, situational factors and lack of awareness of the research prevents any practical applications. While it is not easy to translate educational research into classroom practice, this is happening with HPL. Implementing research-based approaches requires well-designed curriculum, and often face-to-face instruction involves a fair amount of spontaneity. For example, the VaNTH (www.vanth.org) National Science Foundation funded effort has educators and engineers across multiple institutions working with industry to develop curricula and technologies to educate future bioengineers. This undertaking has created new technology-delivered resources as well as a concerted effort to assess, document, and publish educational research on these efforts.

Furthermore, HPL has been used to create a cycle or framework, coined the STAR.Legacy (Software

Technology for Action and Reflection) cycle (Schwartz, Brophy, Xiaodong, & Bransford, 1999). This framework, which organizes student learning into typical phases of inquiry and makes learning visible, uses these four overlapping lenses:

- Learner-centered environments focus on the knowledge, skills, and attitudes that students bring to the learning situation;
- Knowledge-centered environments focus on content that is organized around big ideas or core concepts;
- Assessment-centered environments help students' thinking to become more visible so that both they and their teachers may assess and revise their understanding; and
- Community-centered environments capitalize on local expertise to create a sense of collaboration among students.

These four lenses influence curriculum development and instructional settings. Instructors create knowledge-centered settings by working with students' prior knowledge, skills, and cultural resources, and they create assessment-centered learning by providing for frequent assessments of student progress. Students need opportunities to bring what they know and their beliefs about school subjects in order to have learner-centered opportunities, and both instructors and students can maximize community resources to build community-centered learning that is motivational and collaborative.

There is little doubt that great teachers love their discipline and respect their students, and an emphasis such as the four lenses listed helps to promote an active and involved learning culture. Given today's technological tools, it is conceivable to address each of these research-based variables influencing instruction. Many engineering professors, just like their colleagues in other disciplines, arrive on campus schooled in con-

tent but not in how to teach. They may not intuitively recognize that the single most important thing they should know about their students is their prerequisite knowledge so that they can appropriately begin instruction or provide remediation, if needed.

The Web and its vast array of assessment and survey tools can facilitate gathering data on what students know and what skills they possess. Today's students are Web savvy and anticipate the use of the Web in instructional delivery. Finding out how students progress can be time-intensive, but in-class devices such as the Classroom Performance System (CPS) can be used to generate assessments and to promote interactions. CPS consists of student-operated remote controls and a receiver that records responses to questions by the instructor. The instructor can then display a histogram of student responses in order to decide how best to proceed, given students' understanding. Awareness of the development of students' ability to process and use information is a necessary step in order to actively assess learning in a classroom.

Learner-centered opportunities exist in classrooms where students are questioning and participating. Some refer to higher educational institutions as *ivory towers* where knowledge doesn't seep in from the outside, yet we know this limited view is damaging. In community-centered approaches, efforts are made to promote industry, other institutions of learning, as well as the citizenry in education. The use of instructional technologies facilitates breaking down barriers due to distance and time and, in many engineering classes, students are connecting with others via teleconferencing and the Web.

There are lessons learned from the field of instructional design that go beyond the fundamental principles of starting with instructional goals and student outcomes. From a practical standpoint, the following

instructional design suggestions can help engineering educators and those assisting them develop distance learning curricula:

- Know your students. Discover what knowledge your students bring with them and, in doing so, find out what misconceptions, if any, they have. Don't make assumptions about what they know, and use measures, such as pretests. In distance delivery, it is highly likely you will not be able to see expressions or looks of concern, and you need to have documented evidence of students' baseline knowledge.
- Make your thinking visible. You need to help students apply prior knowledge to new information. Talk through your reasoning process and share with them any pitfalls you experienced as you did your thinking. Pose thought questions for students and if you are using the Web, and make use of a discussion board to get students documenting their thinking and their questions.
- Communicate in multiple ways. If you are teaching at a distance, make yourself available via virtual office hours, the telephone, and email. Share with your students why you do what you do and be enthusiastic. With planning, your excitement in teaching can be evident, despite the distance.
- Analyze the content and look at the structure of knowledge. Is this material well-structured, so that certain instructional strategies work best? Learning tasks can be very different from each other in the kinds of cognitive effort needed, the learning conditions, and ways to assess understanding. For example, there are suggested procedures to teach procedural or declarative knowledge.
- Identify the big themes or the big picture for your students. When doing this, think of ways to visu-

ally display and organize substantial amounts of information. Concept maps can be created and then used as a roadmap for a course. Concept maps reveal the structural patterns in the material and can be used to display the text or lectures in a visual arrangement. Posting the concept map within a course Web site allows students to continually reference it and you can also display this visual in class as a reminder of where you have been and where you are going in the course.

- Find out what your students know. Use ongoing assessment in and out of the classroom. With online testing, students can be provided instant feedback and can take measures that are appropriately geared to their ability level. Make use of survey tools so that you can find out if the course and your teaching strategies are meeting students' needs.
- Teach more than content. Students who are taught how to learn (metacognitive skills) improve in content learning. Make students aware of their learning strategies and help them self-monitor the use of these strategies. By engaging students—for example, in summarizing, questioning, clarifying, and predicting—they will be motivated to learn and are more likely to retain what they've learned.
- Keep in mind that class time is thinking time. That means students are involved and doing more than note taking. Connecting to students who are learning via a computer or a video screen is challenging, but there are ways to do so. Ask questions that are specific (this may require you plan these in advance) and encourage students to come to class prepared and to work in small groups.
- Encourage peer-to-peer learning. Student learning is social and, given that class time is only a fraction of the time they'll

spend on a course, they need opportunities to collaborate with each other. Even students at a distance can work with each other. Often, they can add a unique perspective and enrich the quality of interaction and discussion within a course.

- Keep your focus on your students. Teach from the vantage point that you are to provide students with new knowledge and skills. It isn't about what you teach, but what students will do with what they learn. Make sure that your distance learners have an opportunity to share their materials and to build upon others' understandings.

Engineers, by their very nature, are drawn to a scientific approach to instruction. They cannot, however, be expected to explore instructional science and design without guidance and support from those schooled in learning sciences. This meeting of the minds is ripe for the development of innovative and challenging instructional development. We do know more about how the mind functions and we are documenting what works when we incorporate cognitive science into instructional approaches. In the final analysis, will we be able to produce enough educated people to meet the needs of our high tech society? Time will tell.

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