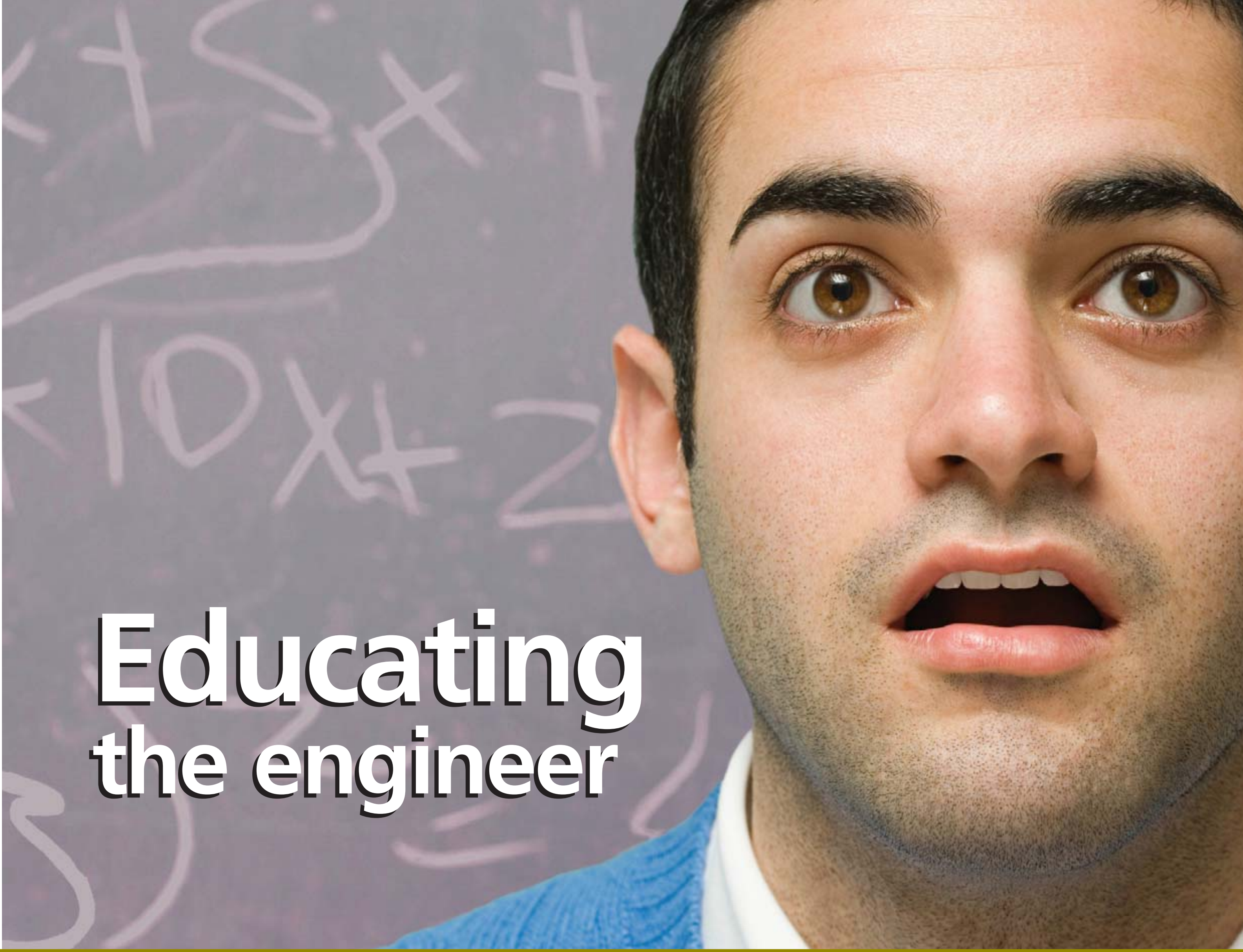

Educating the engineer

By Joseph S. Alford

Part 2 of a two-part series

EDITOR'S NOTE: In the October InTech, University of Texas Chemical Engineering professor Thomas Edgar wrote a story discussing the pros and cons of engineering curriculum in today's universities. This month, a panel of experts shares its insights.

During my 35-year career in bioprocess control in pharmaceutical plants and in mentoring automation engineers, there seems to be a growing gap between what professors traditionally teach in undergraduate process control courses and the needs of today's industrial chemical plants. In testing this perceived gap, it appears there is a problem.

Industry experts agree a problem exists, but there is a diversity of opinion on remedies. In the end, it all comes down to getting students ready for the rigors engineers face in the industrial workplace.

Douglas J. Cooper *(cooper@engr.uconn.edu) is a professor of chemical engineering at the University of Connecticut; the founder of Control Station, Inc., a provider of software solutions for process controller design, tuning, training; and editor of www.controlguru.com, a Web site focused on practical process control issues for*

Ready for industry? Control coursework under scrutiny

THIS IS FOR FAST FORWARD

- There is a growing gap between what professors traditionally teach and the needs of today's plants.
- Experts agree: Problems exists, but opinions vary on a solution.
- One suggestion calls for more hands on training: "Students learn-by-doing."

industrial practitioners. His industrial experience includes three years at Chevron Research Co.:

"Today's control course should provide a practical skill set for students entering the workforce while including enough theory to excite those destined for graduate study. To that end, my control course is grounded in real-world experimentation and the application of theory.

"Students learn-by-doing as they design experiments, collect data, and perform analyses to understand and describe different dynamic behaviors. They discover that data is noisy and that collecting a proper data set is challenging. They experience for themselves the difficulties that nonlinear process behaviors present.

"We spend half the semester working through the 'how's' of practical process control. Student learning is enhanced because a training simulator is visual and hands-on. It provides significant experience, safely and inexpensively, so students are comfortable exploring nontraditional solutions. And modern control installations are computer based, so a video display is the natural window through which the subject is practiced.

"We then work through the theoretical 'why's,' but now the students have motivation for learning theory. And most important, students begin each assignment by confronting a 'real' simulated process on its own terms. Though they eventually learn the benefits of passing through the ideal world of transfer functions on the way to a solution, no project begins there. A real-world approach with significant hands-on practice from a training simulator prepares students for industrial practice while also giving them a reason to explore and appreciate the fundamental theory."

***Russell Rhinehart** (rrr@okstate.edu) is Head of the School of Chemical Engineering at Oklahoma State University, holds the Bartlett Endowed Chair, and has experience in industry (13 years) and academe (21 years). He is an ISA Fellow and is Editor-in-Chief of ISA Transactions:*

"I think the question should be, 'Should control be an undergraduate engineering discipline?'

"Control spans mechanical, structural, and electronic devices; batch and continuous chemical process, staged manufacturing processes, traffic and distribution, business management decisions; and even the national economy. It includes the operation of devices and design of systems to achieve dynamic performance objectives. It includes the mathematical methods for staged and dynamic modeling and optimization, and for noise and fault rejection. It includes reliability, sensitivity, and safety analysis. One undergraduate course in any discipline cannot produce control engineers.

"Control is critical to product quality, safety, and resource and asset management; and control techniques support the developing opportunities in knowledge discovery and action management.

"There is a PE category for 'Control Engineer,' but no U.S. undergraduate programs to support it. By contrast, many other countries have degrees in 'automation engineering' or related titles. However, higher education depends on endowments, government subsidy, or research to complement tuition income, and cannot start a new BS program because the skill is needed.

"Alternately, where there is an existing interdisciplinary strength and faculty and courses in place, a university can offer, relatively easily, a MS degree in a subject to meet the education need. Oklahoma State University adopted this path, and offers a MS degree in Control System Engineering both on-campus and through distance education."

Greg McMillan, *CAP, (greg.mcmillan@emersonProcess.com) is a retired Senior Fellow after 33 years at Monsanto Co. and Solutia Inc, and he is an affiliate professor at Washington University in Saint Louis and a consultant with CDI-Process and Industrial in Austin. McMillan is an ISA Fellow and the author of 16 ISA books:*

"Terry Tolliver and I have taught a course on dynamic modeling and control at Washington University in St. Louis since 2002 that is a requirement for a degree in chemical engineering. The course uses an industrial virtual plant and the ISA book Advanced Control Unleashed. The students are very computer literate and pick up on the use of industrial software from just a few screen prints put into the laboratory exercises. The knowledge gained is generally applicable since the function blocks are based on Foundation Fieldbus used in millions of devices and by over a hundred manufacturers. The configuration environment is also consistent with the international standard IEC 61804. The students learn how to intelligently discuss and use an industrial process simulation, DCS, and data historian that form a virtual plant on their desk.

"Most of the chapters in Advanced Control Unleashed start with an introductory section on "Practice," continue with sections on "Opportunity Assessment" and "Application," and conclude with "Theory." The strategy is to provide the relevance and practical considerations before getting into the theory that offers a deeper understanding."

Diana Bouchard *(dianab@aei.ca) retired from a 26-year scientific career in the Process Control Group at the Pulp and Paper Research Institute of Canada (Paprican). She has also been active in the ISA leadership and most recently served as vice president for Publications:*

"Well, I am neither a control engineer nor a university professor; did I walk in here by accident? In Canada, chemical engineering enrollments are dropping because students see few jobs there. Paradoxically, better measurement and control has made plants operable with fewer engineers and technicians. Will we have anyone to teach?

"We need closer liaison between engineering programs and industry. A technical-vocational college in Montreal has industry representatives on its board and holds review meetings with industrial partners to fine-tune programs and courses. Could this approach be adapted for universities?

"Control is more than continuous process. These sectors are stagnant or declining in North America. By contrast, many batch and discrete processing industries are growing. We cannot maintain enrollments and establish control engineering as a discipline on a base of stagnant or declining industries.

"Control engineering is too much for a one-semester course. Introductory courses don't make you an expert; they help you talk intelligently with one. I would suggest an introductory course (first semester) followed by specialized courses. Want a nodding acquaintance with control? Stop after the first course. Want to learn more? Take a second course. A real control specialist would need a master's or Ph.D., as now."

Cecil Smith, *Ph.D., PE, (cecilsmith@cox.net) has over 40 years experience in process control, the first 13 of which were on the LSU faculty in various positions, including Professor of Chemical Engineering and Chairman of the Department of Computer Science. Since leaving academia, he has provided extensive "continuing education" training and consulting services to industry in continuous and batch processes:*

"The usual academic "process control" course is the result of applying linear systems theory to processes. We need a fresh start, one based on 'you have to understand the process.'

"We need to:

- "Teach fundamental principles, but include only theory relevant to engineering practice.
- "Focus on developing P&I diagrams, using steady-state relationships and steady-state simulation models as the primary source of the required process understanding.
- "Do everything in the time domain. Do not even mention LaPlace.
- "Explain PID in the time domain, including position/velocity, parallel/series, reset windup, initialization/tracking, reset feedback, etc.
- "Introduce time constants and transportation lags. Explain how the PID tuning coefficients relate to these parameters and their impact on loop performance.
- "Deemphasize tuning. If the P&I is right, tuning will be straightforward. Explain how to recognize when a loop is poorly tuned.
- "Cover pumps with variable speed drives and control valves.
- "Dynamic simulations based on basic process mechanisms (not s-domain transfer functions) are valuable teaching tools.

"We need closer liaison between engineering programs and industry. A technical-vocational college in Montreal has industry representatives on its board and holds review meetings with industrial partners to fine-tune programs and courses.

—Bouchard

- “It is not the responsibility of the process control course to introduce students to batch processes. Batch needs to be integrated throughout the chemical engineering curriculum.
- “Focus on basic regulatory control, and do it well. Leave optimization, model predictive control, etc., to subsequent courses and advanced degree programs.
- “Leave safety to other courses, but emphasize process controls should never take an action that would elicit a reaction from the safety system.

“This is the classic question of theory versus practice in engineering education. The key to this problem is to provide control courses that provide basic industrially relevant skills while also providing a fundamental understanding of process control and process dynamics.
—*Riggs*

“Chemical engineers are the crème de la crème of engineers, so take the high road. They deserve education, not training.”

James B. Riggs *(jim.riggs@ttu.edu) has been a professor of chemical engineering at Texas Tech University since 1983. He co-founded the Texas Tech Process Control and Optimization Consortium (www.che.ttu.edu/pcoc/) in 1992, has over five years of industrial experience, and has over 80 technical publications and books on process modeling, control, and optimization:*

“This is the classic question of theory versus practice in engineering education. The key to this problem is to provide control courses that provide basic industrially relevant skills while also providing a fundamental understanding of process control and process dynamics.

“Examples of theoretical topics that are important to a sound conceptual understanding of process control include understanding the unique characteristics of proportional, integral, and derivative control action, the concept of stability, and the differences between linear and nonlinear systems. While it is possible to address these issues in the time domain, the Laplace domain can derive general results while time-domain approaches can usually only be used to demonstrate behavior for specific cases. Moreover, important terminology for the process control field comes directly from linear control theory.

“In addition, it is important to also teach the students the skills necessary to function as entry level control engineers. To be able to perform these duties, they must be able to troubleshoot control loops, tune control loops, and make some basic control design decisions.

“Unless the faculty is willing and able to effectively integrate control theory and industrial control practice into undergraduate control classes, these courses will not fully serve the needs of today’s students and industry. And it is very difficult for a professor to know what is industrially relevant and what theoretical concepts are relevant to industry unless they have direct exposure to the industrial practice of process control.”

Ron Artigue *(artigue@rose-hulman.edu) is professor of chemical engineering at Rose-Hulman Institute of Technology. He has taught process control for over 25 years and has practiced as a consultant with Pitman Moore and Eli Lilly and Co.*

Atanas Serbezov *(serbezov@rose-hulman.edu) is an associate professor in the Department of Chemical Engineering at Rose-Hulman Institute of Technology. He has experience in process control as a practitioner (Honeywell, Inc., Praxair, Inc., and Eli Lilly and Co.) and as an educator (University of Rochester and Rose-Hulman Institute of Technology):*

“At Rose-Hulman Institute of Technology, our required process control class covers process dynamics and control. Our course goals are that our students have a fundamental understanding of process dynamics, have had practical experience for immediate application as process engineers, and have established a basis for advanced study.

“We still teach a number of topics that many have bemoaned as being useless because they ‘never use them (directly) in their job.’ One example is frequency response (FR). However, if one truly wants to fundamentally understand how to filter out process and environmental noise and yet retain real process dynamical information, it is important to understand FR. We are educating our students, not just training them.

“We emphasize the use of simulation tools. Students are taught how to use Control Station to analyze, model, select, and test control system parameters for general transfer function model systems and simulated nonlinear systems.

“Process control today is implemented on complex networked systems where computers (PLC or DCS) connect to external devices, which perform sensing, actuation, and control. It is important to introduce the students to the architecture of modern control systems and also point out the IT aspects of current process control practice.”

Tom Marlin, *(http://www.chemeng.mcmaster.ca/faculty/marlin/default.htm) is a professor of chemical engineering and director of the Advanced Control Consortium at McMaster University in Hamilton, Ontario, Canada. He worked in industry for 16 years:*

“The most striking item in Part 1 (October InTech) is the great disparity between the topics chosen by the academics and industrial practitioners to achieve the goal. I believe the reason is that industrial practitioners are taking a more holistic view of the problem. However, an appropriate academic view exists; in chemical engineering, it is Process Systems Engineering (PSE). PSE technology includes process control, but it integrates modeling, statistics, and optimization, all applied to industrial problems. Clearly, this broad range of topics cannot be addressed in one course. The appropriate response is to offer a suite of required and elective PSE courses that enable an undergraduate to build understanding and expertise in these important areas. We at McMaster have five required and six elective undergraduate courses addressing PSE. Essential automation topics (such as feedback, instrumentation, alarms, SIS, reliability, and trouble shooting) are introduced in required courses, and advanced topics (such as Model Predictive control, statistical process control, and linear programming) are covered in electives. This is a very popular program; over half of our chemical engineering graduates have taken a second control course, a control laboratory, second statistics course, systems-oriented process design, and a rigorous optimization, along with the required topics. If you build it (well), they will come.

"Finally, many topics are beyond the typical undergraduate's background, and as Part 1 points out, continuing education is essential. Many professionals desire opportunities to renew their technical and business skills but often lack support from their employers in North America."

Vernon Trevathan *(vtrevathan@msn.com), consultant, is an ISA Fellow, an ISA vice president with responsibility for training and certification, and the editor of ISA's Automation Book of Knowledge. He worked for Monsanto/Solutia for 35 years in process control and for an engineering company in non-process automation:*

"Loops are an important area for chemical engineers ,and that requires a good understanding of the types of responses and their effect on controllability; process situations that produce those responses; how response is affected by the process design; and basic controller tuning (least important). In addition, an engineer needs some familiarity with loop selection and interaction, advanced control, control of specific unit operations, and control hardware.

"In the past 10 years, process control has expanded well beyond loops, and chemical engineers need to know something about the increasingly complex and vitally important subjects of ISA-88 batch, safety instrumented systems, HMI design concepts, and alarm management.

"Chemical engineers should understand dynamic modeling and the frequency domain, but these topics should not be relegated to a controls course. However, frequency domain analysis techniques (Bode, Nyquist, etc.) and discrete techniques are rarely useful in industrial process control, and a better understanding can be achieved by focusing on the time domain.

"Most chemical engineers will not have primary responsibility for automation systems, so they will not need to know the other ¾ of the Automation Body of Knowledge. And most will not work with non-process applications such as packaging, quality inspection, discrete material handling, Web processes, and motion control, so these should not be included in a process control course. Since undergraduate engineering programs include little automation, the Certified Automation Professional (CAP) credential is proving to be important to demonstrate broad automation knowledge."

Venkat Venkatasubramanian *(venkat@ecn.purdue.edu) is University Faculty Scholar and professor of chemical engineering at Purdue University. His research contributions are in process fault diagnosis and supervisory control, hazard analysis, informatics, and complex adaptive systems, using knowledge-based systems, neural networks, genetic algorithms, and mathematical programming approaches:*

"The time has come for the undergraduate control course to be revamped. However, in doing so, we need to balance the pedagogical priorities and practical needs in order to best serve a wide cross-section of our chemical engineering students. I believe we do not adequately stress the connection between control and process safety and process hazards analysis beyond some perfunctory remarks. I try to address this deficiency by motivating the course through case studies of major chemical plant accidents, such as the Bhopal Gas Tragedy, Piper Alpha Disaster, Flixboro accident, and so on. I try to teach process control in this broader context, which then naturally exposes the students to supervisory control, alarm management, relationship between design and control, and so on. I also have industrial practitioners deliver guest lectures to the students to inject some more practical reality into the course. I think batch control should be a part of the revamped curriculum. I also recommend the idea of using MATLAB/Simulink like tools for interactive open loop and closed-loop simulations of different kinds of processes. We have had success with this approach for a number of years. In addition to the simulations, I would like to incorporate actual experiments to the course."

For a more detailed version of this story, please visit www.isa.org/intech/20061105.

ABOUT THE AUTHOR

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