Random Thoughts . . .

THE SCHOLARSHIP OF TEACHING

RICHARD M. FELDER
North Carolina State University • Raleigh, NC 27695

In his landmark 1990 monograph, *Scholarship Reconsidered*,[1] Ernest Boyer observed that the work of the professoriate involves four different functions: *discovery* (advancement of the frontier of knowledge in a discipline), *integration* (putting research discoveries in broader contexts, making connections across disciplines), *application* (applying the outcomes of discovery and integration to socially consequential problems), and *teaching* (helping students to acquire specified knowledge and develop specified skills and attitudes). Boyer argued that these four activities are equally vital to the academic mission and that the academy should therefore recognize and reward scholarship equally in each of them.

The scholarship of discovery—frontier research—is what most faculty members think of as academic scholarship, and while the scholarship of integration and the scholarship of application may not occupy the same honored position in the faculty incentive and reward system, most professors would at least agree that they exist in principle. It's a different story with the scholarship of teaching. Administrators and faculty members traditionally put teaching and scholarship in non-overlapping categories: some argue that "scholarship of teaching" is a contradiction in terms, and many who concede its theoretical possibility question whether it can be validly assessed.

What is the scholarship of teaching?

According to Boyer, the elements that define teaching as a scholarly activity are mastery of the subject being taught, knowledge of pedagogical methods that have been proven effective at promoting learning and skill development, and commitment to continuing personal growth as an educator. To this list might be added involvement in educational research and development—designing, implementing, assessing, and disseminating innovative instructional methods and materials.

Research in education-related disciplines has a long-established tradition. When done right, it adheres to the same standards of scholarship that characterize good engineering research. These standards have not been routinely observed in engineering education, however, and until relatively recently most of the literature has consisted of variations on the theme, "We tried this method and liked it and so did the students."

This situation has begun to change in the past decade, largely due to the efforts of the National Science Foundation Division of Undergraduate Education and the Engineering Education Coalitions, and a growing percentage of the engineering professoriate is now engaging in serious educational research and development. It is no longer enough to say that everyone liked a method and the students performed well when it was used. The NSF project monitor and the *Journal of Engineering Education* reviewers will inevitably respond with questions such as "What learning objectives were you trying to achieve?" "How well were those objectives met?" and "How do you know—what were your assessment measures, your control populations, your statistical analysis procedures, your evaluation criteria?"

How should the scholarship of teaching be assessed?

Boyer proposes making the scholarship of teaching a legitimate basis for awarding tenure and promotion to faculty members who choose to make education a major focus of their careers. (Not all faculty members should be expected to do so.) This proposal—which has predictably encountered considerable skepticism and some outright hostility from administrators and professors—will gain widespread acceptance only if criteria for evaluating the scholarship of teaching are established and generally agreed-upon. I propose that the evaluation should consist of answering three questions:

Richard M. Felder *is Hoechst Celanese Professor Emeritus of Chemical Engineering at North Carolina State University. He received his BChE from City College of CUNY and his PhD from Princeton. He has presented courses on chemical engineering principles, reactor design, process optimization, and effective teaching to various American and foreign industries and institutions. He is coauthor of the text* Elementary Principles of Chemical Processes *(Wiley, 2000).*

1. To what extent did the teaching qualify as a scholarly activity? Answering this question requires evaluating the faculty member's subject knowledge, pedagogical knowledge, commitment to growth as an educator, and involvement in educational research and development.

2. How effective was the teaching? How well has the faculty member's teaching motivated students to learn and promoted their acquisition of desired knowledge, skills, and attitudes?

3. How effective was the educational research and development? How well were the faculty member's educational innovations designed, implemented, assessed and evaluated, and disseminated? What has been their impact on engineering education?

The data that can be used to answer these questions fall into four categories: *archival data* (lists of courses developed and taught, representative instructional materials and student products; numbers of undergraduate and graduate students advised and faculty colleagues mentored; disciplinary and education-related conferences and workshops attended; journals subscribed to; conference presentations, seminars, and workshops given; articles, books, and courseware published); *learning outcomes assessment data* (test results, evaluations of written and oral project reports and other student products, student self-assessments); *subjective evaluations by others* (student end-of-course ratings, retrospective student and alumni ratings, peer ratings, awards and recognition received, reference letters); and *self-assessment data* (statement of teaching philosophy and goals, self-evaluation of progress toward achieving the goals). A subset of these items gathered into a teaching portfolio provides a sound basis for assessing the scholarship of teaching."

Glassick, *et al.*,[2] suggest the following standards for evaluating educational innovations:

- *Clear goals:* Is the basis of the work clearly stated, the questions addressed important, and the objectives realistic and achievable?
- *Adequate preparation:* Does the scholar display an understanding of existing scholarship in the field and the skills needed to assemble the necessary resources and do the work?
- *Appropriate methods:* Were the methods used appropriate for the goals, applied effectively, and suitably modified when necessary?
- *Significant results:* Were the goals achieved? Did the work contribute significantly to the field?
- *Effective presentation:* Was the work presented effectively and with integrity in appropriate forums?
- *Reflective critique:* Does the scholar critically evaluate his or her own work, bringing an appropriate breadth of evidence to the critique and using the critique to improve the quality of future work?

Faculty members doing educational research that meets these standards are clearly contributing to the scholarly mission of the university. They merit advancement up the faculty ladder—tenure, promotion, and merit raises—no less than faculty members who meet institutional standards for disciplinary research.

Table 1 contains a matrix that may be used to custom-design a process for assessing the components of the scholarship of teaching.

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TABLE 1
Assessment of the Scholarship of Teaching

	Subject Knowledge	*Pedagogical Knowledge*	*Commitment to Personal Growth*	*Innovation and Dissemination*	*Teaching Effectiveness*	*Quality of Innovation*
Statements of teaching philosophy		x	x			
List of courses taught and developed, representative instructional materials	x	x		x		
Representative student products					x	x
Learning outcomes assessment data					x	x
End-of-course student ratings for the past 2-3 years					x	x
Retrospective senior ratings	x	x			x	x
Alumni ratings	x	x			x	x
Peer ratings	x	x		x	x	x
Self-evaluation			x		x	x
Teaching seminars and conferences attended, books read, journals subscribed to		x	x			
Presentations, invited seminars, and workshops on teaching given		x		x		
Published papers and monographs	x	x		x		x
Published textbooks and courseware	x	x		x		x
Awards and other recognition					x	x
External references					x	x

ample is qualitative, one can see the influence of the lower-density inclusion where the wave gets held up, and one can envision how the surface response allows a map of the subsurface to be generated. From a mathematical viewpoint, this example helps illustrate typical hyperbolic behavior: the response of the interior to a change at the boundary is delayed, but then felt at full strength once the wave reaches a given point. Using this example in the classroom, an otherwise dry discussion of characteristic lines for a hyperbolic equation can become more captivating.

CONCLUSIONS

The use of PDEs in the undergraduate curriculum often has mixed results: Important topics cannot be modeled without PDEs. On the other hand, the simplicity of solution domains for analytic problems often makes for abstract relationships to real engineering problems, and the mathematical details of an analytic solution can distance students from the original objectives.

This paper presents effective uses of modern numerical software for solving real engineering problems at the undergraduate level, which is an increasingly popular approach among chemical engineering educators. The quick learning curve for certain numerical software allows students to begin exploring a model's behavior almost immediately. Classroom time can then be used to break down conceptual barriers associated with PDEs. It is hoped that this approach lays a better foundation and better prepares students for later material on solution techniques, either analytical or numerical.

ACKNOWLEDGEMENTS

The author would like to acknowledge Charles Varnado for providing the numerical code used to generate Figure 1, and to acknowledge the anonymous reviewers for very insightful comments on the original manuscript.

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The more types of assessment data collected for a specific component (column of the matrix), the more reliable, valid, and fair the evaluation of that component. For explanatory notes and literature citations on the different assessment tools, see Reference 3.

How might the scholarship of teaching be included in tenure and promotion decisions?

Many academic institutions have begun to acknowledge the scholarship of teaching as a valid component of tenure and promotion (T/P) applications. An approach being taken by several of these institutions is to allow faculty members to allocate variable percentages of their total effort to teaching, research, and service, with minimum percentages being specified for each area. If more than a certain percentage is allocated to teaching, educational scholarship must be included in the faculty member's activities and a teaching portfolio containing a subset of the items in Table 1 must be included in the T/P dossier. A review committee assigns separate numerical performance ratings to each of the three areas and weights the ratings by the specified percentages to calculate a composite rating, which provides the basis for the decision on tenure or promotion.

For ratings of the scholarship of teaching to be reliable and valid, the evaluating department should take the following steps:

◧ *Formulate and announce an assessment and evaluation plan.* Decide which items listed in Table 1 will be collected in the teaching portfolio, taking into account both institutional guidelines and considerations specific to the department. Choose a system to rate each of the items in the portfolio (e.g., rate each item on a scale from 0 to 10), weighting factors for each item, and weighted scores that serve as criteria for ad-

equate and superior scholarship. Describe the rating system to all departmental faculty members who may wish to include educational scholarship in their credentials and display several examples of excellent portfolios as models.

- *Provide training to portfolio raters.* Give detailed explanations of the evaluation criteria to faculty members who will be serving as raters and provide guided practice on sample portfolios.

- *Collect at least two independent ratings of each portfolio submitted and have the evaluators reconcile their ratings to arrive at a consensus rating.* Incorporate the consensus rating into the overall tenure/promotion dossier evaluation process.

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review articles and has received many invitations as an invited lecturer. He supports his research through a number of NSF grants and an industrial/university consortium, CIPAC (Computer Integrated Process Operations Center), at Purdue. He was one of the founders of CIPAC and served as its director until this year when Professor Gavin Sinclair took over. In 1984 he won the Computing in Chemical Engineering Award of the Computing and Systems Technology Division of AIChE. He was again recognized by AIChE for his accomplishments when he was named a fellow in 1994. In that same year he also won the best paper award from *Computers & Chemical Engineering* for the paper by Jayakumar and Reklaitis, "Chemical Plant Layout Via Graph Partitioning: Part 1. Single Level (*Comp. & Chem. En.,* **33**, 441, 1994). 1994 was a very good year for Rex since that year he also won the ASEE Chemical Engineering Division lectureship award. His award address on "Computer-Aided Design and Operation of Batch Processes" can be found in *CEE,* **29**, 76, (1995).

Of course, much of the real work of research is done by graduate students. Rex has been advisor or co-advisor for 28 PhD students and 37 MS students. He currently advises or coadvises eight PhD students and one MS student. Seven of his past students are now professors: A. Elkamel (Kuwait University), Carl Knopf (Louisiana State University), I. Karimi (National University of Singapore), B.S. Lee (Pukyong National University), E.S. Lee (Dongguk University, Korea), I.B. Lee (Pohang University, Korea), and G. Yi (Kynghee University, Korea).

Rex has also proved himself to be a good citizen of the chemical engineering community. He has served as secretary, vice-president, and president of CACHE and continues to serve as a trustee of that organization. Equally active in AIChE, particularly in the Computing and Systems Technology (CAST) division (in which he has held all of the offices), he was an elected director of AIChE until December of 1999. He has also been an active member of the Council for Chemical Research and has served on its governing board. He has co-edited several volumes of conference proceedings dealing with process design, simulation, computer graphics, and optimization. He has been Editor-in-Chief of *Computers & Chemical Engineering* since 1994 and was Co-Editor-in-Chief for the eight years before that.

In his research and professional activities, Rex has always been a good team player. He has collaborated with a number of past and current faculty at Purdue on papers, including Paul Andersen, Gary Blau, Frank Doyle, Lowell Koppel, Martin Okos, Joe Pekny, Dan Schneider, Bob Squires, Venkat Venkatasubramanian, and Jack Woods. He has also collaborated on papers and edited proceedings with a number of well-known chemical engineering professors from other schools, including Larry Biegler, Brice Carnahan, James F. Davis, Tom Edgar, Ignacio Grossmann, Dave Himmelblau, Richard Mah, David Rippin, John Seader, Jeff Siirola, Aydin Sunol, and Doug Wilde.

While involved in this work at Purdue, Rex continues to live the good life in West Lafayette, helping raise his two sons and being, in Janine's words, "a wonderful father" who takes the role very seriously—when they were much younger, he would tell the boys wonderful stories of knights and pirates, and take them fishing or sailing, and for family-favorite ski trips in Colorado. George earned his bachelor's degree in history from Purdue, his master's from Wake Forest, and is now working on his PhD in history at Northeastern University in Boston. Victor is a junior in electrical engineering at Stanford University.

Sailing has remained an important part of Rex's life. For sixteen years he participated in the famed Chicago-to-Mackinac race and even won his class a few times in a 34-foot Islander—but most of the time he finished in the middle of the pack. His family, who did not race with him, would watch the boat leave Chicago and then drive to Mackinac Island to watch the boats arrive there. They did, however, enjoy sailing with him in his 19-foot Lightening.

In addition to being close enough to sail on Lake Michigan, the Lafayette area is near enough to visit family in Chicago for the holidays. Rex remains close to his mother and sister and has become close to Janine's large, rowdy extended family.

We are proud to have Rex Reklaitis at Purdue. He is an honest, generous, witty colleague with high standards. Fade out to the tune of *The Wabash Far, Far Away.* ❐