The View from the Top: Leaders’ Perspectives on a Decade of Change in Engineering Education

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Abstract

Researchers at The Pennsylvania State University’s Center for the Study of Higher Education conducted 27 semi-structured one-hour interviews with the deans, chairs, faculty, industry leaders, and association officers who comprise the leadership of national engineering education societies and the Accreditation Board for Engineering and Technology. During the interviews, these leaders described what they believe are the two most significant changes in the field of engineering education during the last decade. This article discusses the sources and pervasiveness of each change, how each change has influenced policy or practice in engineering education, and the best ways to encourage faculty involvement in the change.
I. Introduction

In response to pressures from industry, Accreditation Board for Engineering and Technology (ABET), and funding agencies, many colleges of engineering have increased their efforts to improve the quality of students’ undergraduate education experience during the last ten years. Deans, chairs and faculty interested in improving their undergraduate programs are now faced with an exciting--but sometimes bewildering--array of possible changes they might attempt at their own schools. Confronted with so many pressures to change, so many reform options to choose, and faculty resistance to change, engineering administrators and faculty may benefit from a national perspective on engineering education reform. To gain that perspective, researchers from the Center for the Study of Higher Education (CSHE) at The Pennsylvania State University asked 27 leaders in engineering education to share their opinions: (1) about the sources, impact, and pervasiveness of recent changes in the way undergraduate students are prepared for careers in engineering, and (2) about how to involve faculty in making such changes. Leaders’ suggestions for involving faculty in engineering education reforms emphasized changing faculty reward systems, using accreditation “as a hammer,” providing time and resources for training, and encouraging faculty to gain industry experience.

Engineering education leaders identified 6 main sources from which they learn about engineering education reforms. Most participants reported that they learn about changes in engineering education from attending professional conferences (e.g., FIE, ASEE, IEEE Education Society, etc.) and reading the Journal of Engineering Education. They also reported learning about changes through informal networks (e.g., talking with friends/colleagues involved in engineering education) and formal networks (e.g., university’s connection with industry partners). Some
participants suggested that they learn about changes in engineering education from industry, government agencies, and business magazines.

II. Methods

The sample consisted of 27 national leaders in engineering education including 25 men and 2 women. The list of leaders (defined as those individuals likely to have a national perspective on engineering education) consisted of senior officers and board members of the American Society for Engineering Education (ASEE) and ABET. All 27 individuals in the sample have their primary affiliations with universities (21), associations (4), or industry (1). Of the participants employed in academic settings, 12 are deans of engineering colleges, 8 are faculty members, and one is a university president.

Data collection involved semi-structured individual interviews. Most of the interviews were conducted face-to-face during the 1998 annual ASEE meeting in Seattle, WA. Telephone interviews were conducted with those participants who were unable to meet in person. Six researchers interviewed between three and seven participants each. Interview protocols were used to maintain consistency across interviews. The interview questions focused on the following themes:

- What do the leaders perceive to be the two most significant changes in engineering education during the last 10 years?
- What do the leaders believe to be the sources and pervasiveness of the changes?
- How—in the leaders’ opinions—has each change influenced policy and practice in engineering education?
- What are the best ways to encourage faculty involvement in the changes?
Interviews were audiotaped and field notes were taken. The audiotapes were transcribed. The researchers then analyzed the interview transcripts and field notes. Data analysis proceeded through five, non-linear stages: organizing the data; generating categories, themes, and patterns; challenging emerging hypotheses; searching for additional, plausible explanations; and writing the results [1].

III. Engineering Education: A Decade of Change

Changes in educational practice identified most often by leaders fell in five main categories. First, many leaders discussed the incorporation of design in engineering curricula, focusing on the “art and practice” of engineering, and not just engineering science. Second, leaders also described an increased emphasis on teaching, from innovative teaching methods, to incorporating teamwork, to focusing on students as stakeholders and customers. Third, advancements in computer technology have changed the teaching of engineering both in the classroom and at a distance, according to the leaders we interviewed. Fourth, leaders described the need for more broad-based curricula: curricula that are integrative and interdisciplinary within engineering and curricula that incorporate “non-technical” or “softer” elements of engineering. Fifth, leaders mentioned that changes in ABET’s accreditation criteria alter the way that engineering courses are developed and programs are evaluated. Other changes in engineering education included: funding for undergraduate education; students using their engineering backgrounds as stepping stones into professional fields (e.g., law, medicine, business); industry’s revitalized interest in engineering education; and incorporating the hard sciences (e.g., chemistry, physics, math) into engineering curriculum. Interestingly, no one identified increasing the diversity of engineering graduates as a significant change in engineering
education. This analysis will focus on the five changes mentioned most frequently by leaders. Table 1 lists the frequency of participants’ responses.

IV. Design: The “Art and Practice” of Engineering

When asked about the most significant changes in engineering education during the last decade, 10 of the 27 leaders identified the use of design in the curricula. If a leader did not mention design as an important change we inquired, “In addition to the changes you mentioned, have there been any significant changes in the way that design is taught to undergraduates or the role of design in the undergraduate curriculum?”** They were also asked their opinions on the sources of change in design, how changes in teaching design have influenced policy or practice in engineering education, and the extent to which all colleges of engineering are now incorporating design in their courses and curricula.

Of the 26 engineering education leaders who discussed design issues, 24 believed significant and positive changes have taken place in the past ten years in the way design is taught to undergraduates. Two other leaders thought there have been some--but not enough--positive changes in the way design is taught and included in the undergraduate curriculum. For example, some leaders focused on first-year design courses. One leader stated: “One thing that I think many schools have looked at is . . . ‘How do I bring in the process of design at the earliest possible stage, which often times is in the first year of a student’s engineering program and carry this thing through to the end?’ This is certainly something that’s being done more and more. And I think this is very significant. This is a very significant change.” Others mentioned infusion of design throughout the curriculum. One leader was glad that design is no longer confined to capstone courses. According to him, “One of the more dramatic changes is the fact that in many institutions, and this includes my own, students are encountering design experiences
across the curriculum, all the way from the freshman year all the way through to graduation at senior level.” An industry leader, however, believed that engineering educators still have a long way to go before they will teach design effectively. This leader stated: “I don't see [changes in teaching design]. I think we're still to the stone's edge of the traditional with very little emphasis on design only because [faculty] do not understand design. I think we can look forward to the time that will change. I don't know how long a time we're talking about, because obviously it takes academia a while to make those changes.”

A.  Sources of Changes

Leaders mentioned one or more of the following as sources of change in the way design is taught or incorporated into the curriculum: industry (12), ABET (7), technology (4), administrators’ desire to increase retention (2), societal and economic issues (2), and particular faculty members (1). One leader said, for example, “I think ABET played a role in [integrating design]. I think industry played a role in it because graduates needed to be able to design and have a little bit better experience and exposure than they had. And I think, again, we have the globalization and the economy. In order to be competitive, you’ve got to get better. And I think the integration of design surrounds the curriculum as opposed to just one spot at the end, enabled ties between design and other factors that are important, such as economics. That’s certainly an obvious one, but [so are] some of the social implications of a particular design.” Only one leader identified NSF-funded coalitions as a source of these changes. This individual noted that first-year design had been done before, but that it had gone out of fashion. “Now, in part due to NSF funding to make the freshman year a significant experience, people are coming back into having the idea of teaching design, or at least some component of the design process, back into their early year.”

An overwhelming majority of the leaders we interviewed felt that most engineering schools
emphasized design much more than they had 10 years before. Most attributed the pervasiveness of the change to ABET. As one leader said, most schools teach design now “because it became a very specific accreditation requirement in the in the early ‘90s” [2].

B. Getting Faculty Involved

To encourage faculty to incorporate design in their curricula, the leaders suggested changing the reward system to weight teaching more heavily and to create a more equitable balance between the amount of research and teaching activity faculty members perform. In addition, two leaders proposed that faculty participate in training or industry internship programs to see how design is used in the workplace. One leader emphasized that departments and colleges must fund faculty to develop and implement innovative courses. Another suggested that engineering programs hire faculty who are enthusiastic about design and practical engineering applications.

V. Emphasis on Effective Teaching

Ten of the 27 participants reported that colleges of engineering are focusing more and more on undergraduate education. One leader even said, “administration and faculty should embark on a campaign to celebrate teaching.” Leaders viewed the increased emphasis on effective teaching through two lenses: 1) faculty teaching students and 2) students as stakeholders and learners. According to the leaders, the importance of and interest in teaching undergraduates and teaching effectively has been a hot topic among engineering educators over the past 10 years. A dean of an engineering college stated that faculty at his institution have “been interested in working together as individuals and in teams to improve their teaching, to understand the principles of good teaching, to understand better the process of learning. Not all, but a significant number have made a commitment to being better and better teachers in the classroom and as advisors.” Others reported that the emphasis on classroom teaching is witnessed by faculty implementing
innovative teaching methods—including design, teamwork, and computer technology—and by the effort to evaluate the success of various teaching methods. One individual noted that “folks are saying, ‘We need to stop and address how we can really figure out if this is really making a difference where our students are concerned. So I see that as something that kind of hit me in the last couple of years…. I think there’s a renewed interest in the assessment and evaluation [of teaching methods], maybe tied to ABET 2000.’”

In addition, leaders believed a shift in paradigms occurred during the last ten years from assessing faculty on research activities only to assessing faculty on teaching ability and student learning. One leader said, “…it is a different paradigm in assessing the scholarly dimensions of a faculty member to be more than just in research—traditionally scholarship of discovery—and more recently, scholarship of integration, but now exploding that to include scholarship of teaching and application.” This paradigm shift has lead to a greater emphasis on teaching and faculty interest in engineering education.

Two of the leaders suggested that a large proportion of engineering schools now acknowledge students’ different background characteristics and learning styles and consider these attributes when developing effective teaching methods. One leader said, “I think it’s the television and the computer, and video games—computer games—that they can play at home either on their television set or on their personal computer…I think the interactive nature of those games—the live action—I think that’s what has changed the way students learn. They are not nearly as passive as my peers were when I was a college student.” Taking into account the interactive learning style of many college students, leaders believed that some faculty are integrating more group work, shorter lecture periods, and specific processes for students to provide feedback on what they learned into their classrooms.
A. Sources of Changes

Three of the leaders asserted that public dissatisfaction with academe was the impetus for the pedagogical changes in educational practice. One respondent named Charles Sykes’ *Prof Scam* [3] while another cited Ernest Boyer’s publication *Scholarship Reconsidered* [4] as having influenced educators to reexamine and improve undergraduate education. Another leader pointed to the public dissatisfaction with universities’ emphasis on research. Furthermore, leaders said that industry has played an increasingly important role in engineering education. Students as customers want to gain certain skills and knowledge in order to work in particular fields. Likewise, industry wants to employ graduates who have content knowledge and teamwork and lifelong learning skills.

B. Getting Faculty Involved

The best way to involve faculty is to reflect its importance in the recognition and reward system (i.e., promotion and tenure). “Our provost has said…when it comes to discretionary salary pools, that she wants about half of the raises distributed on the basis of teaching quality and the other half on the basis of research quality.” Other leaders proposed training, exposure to new methods, attending education conferences, and experience.

VI. Computer Technology

Most of the leaders agreed that a large-scale implementation of computers in research and teaching occurred during the last 10 years. According to one participant “all of the [engineering] disciplines have to have a good strong understanding of the computer work world. And as a result, we find more and more employers, in fact, employers insisting that most of our graduates have a strong engineering computer background.” One leader suggested, however, that some
institutions lack the financial resources to be at the forefront of technological revolution and still rely heavily on traditional teaching methods.

Technological innovations required faculty to incorporate new information technologies in the classroom and to add computer laboratory courses to the curriculum. One leader listed several ways computers modified engineering education: “The kinds of things, to me at least, that [computers in education] can be most useful is to use the interactive—and it could be CD ROM; it could be web based; it could be a combination of the two—use the interactive multimedia experiences to introduce new material, concepts, drills. Have tutorial kinds of experience where students will be lead from one question to the next depending on outcome. I think you’re going to see that—at the more advanced places—replace a lot of stand up lecture.” According to the leaders we interviewed, advances in technology increased institutions’ outreach capabilities and the manner in which courses are delivered (e.g., distance and continuing education). One leader asserted, “Another player in [technological advancement] has been this synchronous learning network.” In addition, an engineering college dean, reported, “I can and already am offering courses world wide— independent of locations, independent of time zones— and can do that in a cost effective manner because of technology.”

A. Sources of Change

The leaders believed that the competitive environment—in industry for competent employees and in higher education for students—drives technological progress and its incorporation in the curriculum. The leaders agreed that the advent of personal computers, accessibility to computers, and the development of auxiliary equipment and software (printers, the Internet, etc.) made it easier and necessary to provide students with a strong engineering computer background. Three leaders indicated that the use of computers in industry prompted higher education
institutions to use computers in the classroom. For example, one leader said, “employers that come to the campus almost insist…. Well, they insist that if you don’t have it [computer education], they don’t want to come to your school because that’s a prerequisite for being hired anymore.” Another leader reported that faculty members’ commitment to computer education is the driving force for technology in their classrooms.

B. Getting Faculty Involved

Most of the leaders believed that training faculty how to use engineering computer programs as well as using computers as educational tools would encourage faculty to incorporate more sophisticated computer applications in their classrooms. Three of the leaders intimated that some faculty might be resistant to technology. One participant said, “You have to convince faculty that technology will help them work smarter, not harder.” Another suggested that if exposed to the latest computer applications, many faculty would become interested and learn more on their own.

VII. The Well-Rounded Engineering Student: The Need for a Broad-Based Curriculum

Seven of the education leaders described the need for more broad-based curricula: curricula that 1) are interdisciplinary within engineering and 2) incorporate the “softer,” non-technical elements of engineering. The leaders believed that, more so now than 10 years ago, employers seek students with a broader educational background. For instance, one leader said, “more and more companies are looking at students who have a broader background of education…in the ‘60s, ‘70s, and ‘80s we hired electrical engineers, mechanical engineers, and chemical engineers. And now more and more employers are saying, ‘We want an engineer who is capable of stepping across some of the boundaries that were originally set up.’”
In addition to being knowledgeable across disciplines, engineering students must learn the non-technical aspects of engineering. According to the leaders, the curricula must therefore include the “largely non-technical items such as the six non-technical items contained in the 11 criteria, number 3, of ABET 2000. Things such as teamwork, communication skills, leadership abilities, knowledge of ethics and world economy and so on. Things non-technical. The things that most faculty don’t normally look at in engineering education.” Problems emerge, according to the leaders, when engineering educators are not trained or used to doing non-technical things in their educational spheres. Therefore, it’s often left to others from other colleges or other disciplines, including retirees and industrial visitors, to help. There’s only a small minority of engineering professors, for example, who would want to teach a course in entrepreneurship or ethics…. And the approach being pushed by ABET is to incorporate these non-technical things—to infuse them—into the curriculum. Even that’s not easy. You go to a person, a faculty member teaching electromagnetics and Maxwell’s equations and say, ‘Put some ethics into your course.’ And he’s going to look at you like you’re crazy, or she. That’s a problem.

A. Sources of Change

Six leaders believed industry was the driving force behind broadening the curriculum while three leaders said that accreditation was the source. One leader summed up the sources of change when he said:

Probably 10 or 12 very large engineering institutions decided that they didn’t like the accreditation process and standards that were in place at the time and they threatened to secede from ABET. They got everybody’s attention and ABET began working with
respect to looking at changes. And during that process, there were some industry movements saying that engineering graduates were missing some key attributes they felt needed to be there. And in those cases, they wound up including what we call the “soft” skills: that would be oral communication, the ability to work in teams, understanding the society you are practicing in… .So I think the movement is driven by both industry and by engineering institutions themselves.

All of the leaders who discussed broadening the curriculum believed the process is in the beginning stages. One leader stated: “The writing is on the wall because of ABET criteria, but few institutions have implemented [a broad-based curriculum] so far.” Another participant echoed those sentiments: “I think the change, in terms of what is happening in engineering education, is not nearly as great a most people think. I think that we’re just at the start.”

B. Getting Faculty Involved

The leaders discussed three ways to involve faculty in developing a broader curriculum and incorporating non-technical elements in their engineering classrooms. First, they suggested “bombarding faculty with information” through workshops, education conferences, and presentations during faculty meetings. The leaders also reiterated the importance of rewarding faculty who adopt the changes with promotion and tenure. Third, one leader suggested “that maybe one way would be for some of the faculties to go out and work in industry on a sabbatical or something to see what industry really needs. Or have faculty visit employers on a routine or periodical basis to see what employers need.”

VIII. Accreditation/Assessment

Seven leaders described the fifth significant change in engineering education: the emphasis on program assessment in accreditation criteria. According to an industry representative, the
“number one [change] would have to be the ABET engineering criteria because that actually changes the way that programs are evaluated and changes the way courses are put together.” ABET 2000 criteria require institutions to evaluate and document the quality of their programs and student learning outcomes. One leader believed that the new accreditation process was more than a set of accountability measures. He said the new accreditation policies “allow much more flexibility and encourage innovation and also accountability in the programs.” At the time of the interviews (June and July, 1998), only a handful of institutions had been through the accreditation process using ABET 2000 criteria. All engineering schools, however, will have to implement assessment and evaluation mechanisms prior to their next ABET review.

A. Sources of Change

According to the leaders, several influential engineering schools and industry were the driving forces behind ABET 2000. According to one leader, a large group of engineering schools “collectively addressed ABET and the engineering accreditation commission and appealed for the changes…. Industry had a very significant impact and input into the generation of EC [Engineering Criteria] 2000 as well. So the result was that ABET stopped and looked at what it was doing. NSF funded some workshops; ABET brought industry people and deans and all of the constituencies into these workshops. People sat down and talked about what needed to be done. As a result of that activity, it was decided we would throw the criteria away and start with a clean sheet of blank paper. Which is what, in fact, happened.”
B. Getting Faculty Involved

As with other changes, the leaders believed that providing assessment workshops and changing the nature of the promotion and tenure process to reward teaching that reflects accreditation criteria would be an effective way of involving faculty. Generally, the leaders acknowledged that administrators and faculty must follow ABET 2000 guidelines for their institutions to be accredited.

IX. Involving Faculty

Leaders suggested multiple strategies to involve faculty in national engineering education reforms (see Table 2). The approaches fell in three categories: rewards, training, and whom to involve. Regardless of the method used, however, support—practical, moral, and financial—from deans, department chairs, administrators, and other faculty is imperative for implementing any curricular innovation. Support for education and educational reforms must also come from professional research societies and organizations within engineering and its disciplines.

All leaders indicated that the reward structure for higher education faculty (i.e., salary, promotion, and tenure) ought to change. For example, one leader stated, “Well, the answer is very simple: change the reward structure. We traditionally have not done that. We’ve not rewarded faculty members for creative educational activity. We reward them for creative research activity.” Many leaders acknowledged that this idea is not a new one. They also admitted, however, that few—if any—institutions weigh teaching activity as heavily as research activity in promotion and tenure decisions. One way of rewarding teaching activity is to provide faculty with paid time off for course development. Developing and implementing innovative instructional methods requires time that faculty scarcely have. One leader said that most faculty are employed under 9-month contracts and, as a result, often seek research grants to receive a
paycheck during the summer. He suggested that deans use salary savings to compensate faculty during the summer so that faculty may focus on developing courses. Departments may also seek course development grants offered by their university, college of engineering, the National Science Foundation, or other organizations.

Training, broadly speaking, is the second strategy identified by the leaders for involving faculty in changes in educational practice. A number of leaders suggested that faculty would buy into many of the significant changes if only they knew the nature of the changes and how to incorporate them. To accomplish this goal, many participants recommended that faculty participate in education conferences and workshops. Interestingly, three leaders suggested that faculty participate in paid industry internship programs to learn first-hand what skills students need to prepare them for engineering careers. The internships might be financed either by faculty members’ institutions or industry, but should always be endorsed by their university administrators. Industry internships may take place during the summer months or while a faculty member is on sabbatical. Universities may also foster strategic alliances with industry by inviting industry representatives to instruct a course or participate in curriculum development. For example, an industry leader reported, “if we engage them [industry representatives] in faculty internships…We always send our people out to them because that’s the way we get to know what one another does, is actually conducting their business…. We have what we call the Faculty Fellows program, which is an internship. It’s highly recognized across the US as very successful.”

In discussing faculty involvement, the leaders were split on whom to involve in educational reforms: junior or senior faculty. Some leaders felt that junior faculty would be more familiar with computer technology and have more enthusiasm for teaching innovations. Other leaders
worried that encouraging junior faculty to focus on teaching would prove detrimental to their earning tenure under the current system. They believed that senior faculty, having established research careers, would have more time and flexibility to devote to teaching innovations. In contrast, some other leaders believed that involving senior faculty would send the reform into retirement when the senior faculty members retire. The key to institutionalizing any reform is to secure endorsement of junior and senior faculty, administrators and other professionals.

X. Conclusion

During the last decade, many colleges of engineering sought to improve the quality of students’ undergraduate education experience. Industry, accreditation, and funding sources were the driving forces behind many changes in educational practice. This study sought to provide a national perspective on engineering education reform and practical methods for involving faculty in the changes. Twenty-seven leaders in engineering education reported on the sources, impacts, and pervasiveness of recent changes in the way of undergraduate students are prepared for careers in engineering and about how to involve faculty in making such changes. Changes in educational practice identified by the leaders fell in five main categories: the incorporation of design throughout the curricula; an emphasis on effective teaching; the influx of computer technology in the classroom and beyond; the need for a more broad-based curricula; and a new interest in assessment due in large part to ABET 2000 accreditation criteria. Two approaches to encouraging faculty to adopt changes in educational practice most commonly cited by the leaders were changing the reward structure and providing opportunities for faculty to learn about significant changes in educational practice in workshops or industry internships. Whatever approach administrators use, unilateral support is necessary for a reform to become institutionalized.
References


Text of Footnotes

Page 1: *An earlier version of this paper was presented at the Frontiers in Education conference in San Juan, Puerto Rico, November 1999. The study was supported in part by a grant from the Engineering Education and Centers Division of the National Science Foundation to Howard University (Grant No. 634066D) to support the Engineering Coalition of Schools for Excellence in Education and Leadership (ECSEL). The opinions expressed here do not necessarily reflect the opinions or policies of the National Science Foundation and no official endorsement should be inferred.

Page 5: *CSHE conducted these interviews while evaluating the NSF-funded Engineering Coalition of Schools for Excellence in Education and Leadership (ECSEL). Two of ECSEL’s primary goals are to incorporate design in undergraduate engineering curricula and to increase the diversity of engineering graduates. Therefore, interviewers also asked specific questions about design and diversity.
Table 1  Twenty-seven Leaders’ Perceptions of Two Most Significant Changes in Engineering Education during the Last Ten Years

Table 2  Changes in Engineering Education and Recommendations on Involving Faculty
Table 1. Twenty-seven Leaders’ Perceptions of Two
Most Significant Changes in Engineering Education
During the Last Ten Years

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<th>Change</th>
<th>Frequency</th>
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<td>Design</td>
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<td>Emphasis on Effective Teaching</td>
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<td>Computer Technology</td>
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<td>Broad-based Curriculum</td>
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<td>Accreditation/Assessment</td>
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<td>Funding</td>
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<td>Engineering as Professional Stepping Stone</td>
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<td>Incorporating Science in Engineering</td>
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<td><strong>TOTAL</strong></td>
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Table 2. Changes in Engineering Education and Recommendations on Involving Faculty

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<tr>
<th>Changes</th>
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<td>Training</td>
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<tr>
<td>Design</td>
<td>Paid faculty industry internships;</td>
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<td><em>Workshops on group skills and collaborative learning</em></td>
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<td>Effective Teaching</td>
<td>Attend education conferences;</td>
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<td></td>
<td>Exposure to new methods;</td>
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<td><em>Mentoring</em></td>
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<td><em>Teach graduate students how to teach</em></td>
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<td><em>Incorporate comprehensive assessment of teaching and student learning</em></td>
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<tr>
<td>Computer Technology</td>
<td>Workshops on new engineering programs and educational uses of computers;</td>
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<td></td>
<td><em>Collaborate with computer support services</em></td>
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<td>Accreditation</td>
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<td></td>
<td>Provide information about ABET guidelines;</td>
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<td></td>
<td><em>Collaborate with university assessment offices</em></td>
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NOTE: *Italics* denote recommendations suggested by the authors.
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