

The Role of Centers for Teaching and Learning in Improvement of Undergraduate Engineering Education¹

PI: Pratibha Varma-Nelson, Co-PI: Terri Tarr, and Project Evaluator: Stephen P. Hundley

Abstract

Many higher education institutions have a Center for Teaching and Learning (CTL) whose mission is to advance teaching excellence, foster innovation, and translate educational research into practice. However, those centers are often underutilized by the faculty and schools they serve. Most centers have a core group of faculty who participate regularly; however, the majority of faculty members are not involved in center activities. This report will detail the findings from an NSF-funded project titled *The Role of Centers for Teaching and Learning in Improvement of Undergraduate Engineering Education*. The two-day CTL/Engineering Education workshop brought together CTL directors, engineering faculty, and engineering school administrators. The workshop agenda was to outline strategies for enhancing partnerships between CTLs and schools of engineering to improve undergraduate engineering education. The following report will introduce the context and goals of the workshop; highlight findings of a pre-workshop survey of CTL professionals; present an overview of the workshop discussion strands; discuss insights and strategies gained from the workshop; and present recommendations for CTLs, engineering faculty, and engineering administrators.

Introduction: Context and Project Goals

The primary mission of the CTLs is to advance teaching excellence at their institutions while supporting faculty through a collaborative approach. The CTLs offer a wide array of programs, events, and services that foster innovation and translation of educational research into practice. However, schools of engineering often do not draw upon the expertise of the CTL staff and their knowledge of learning theory; perhaps because engineering faculty are disciplinary experts first, and may not see the value in professional development activities that are not tied to their content (American Society for Engineering Education, 2009). Partnerships between CTLs and schools of engineering could have more impact if they focus on developing opportunities that begin with analysis of teaching challenges and focus on content (Layne, Froyd, Simpson, Caso, & Merton, 2004). In addition, CTLs can facilitate reflective conversations about how people learn (Bransford, Brown, & Cocking, 2000), learning outcomes, and how to develop and assess students with respect to those outcomes. Furthermore, some CTLs are focused on helping faculty transition from effective teaching to the Scholarship of Teaching and Learning, and recently NSF sponsored two Webinars, “Advancing the Levels of Inquiry in Teaching and Learning: Considerations in Moving from Effective Teacher to the Scholarship of Teaching and Learning (SoTL).” There are a few articles focused on advancing the levels of inquiry in engineering

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education (Streveler, Borrego & Smith, 2007) and SoTL in engineering (Wankat, Felder, Smith & Oreovicz, 2001).

The *Role of Centers for Teaching and Learning in Improvement of Undergraduate Engineering Education* Workshop was held July 1-2, 2010 in Arlington, Virginia. This workshop brought together over 40 professionals representing directors of CTLs, engineering faculty, and administrators of schools of engineering; there were also 9 NSF program officers and other stakeholders in attendance. The principal goals of this project were:

1. To outline strategies for leveraging resources and expertise at existing CTLs;
2. To identify programs, support, and resources from CTLs appropriate for engineering faculty to enhance their lifelong development as educators;
3. To identify ways to inform the planning of professional development programs by utilizing faculty insight into student learning issues and difficulties with content; and
4. To prepare recommendations for how engineering administrators could support and recognize educational innovation and professional development through a partnership with CTLs.

Pre-Workshop Survey of CTL Professionals

In support of the project goals, a pre-workshop survey of CTL professionals was conducted in order to inventory present offerings related to professional development, in general, and to determine interests, needs, and perceptions surrounding *engineering* professional development, in particular. A purposeful sample of 98 CTLs were identified and invited to participate, drawn from the Top 100 Engineering Schools, as listed by *U.S. News and World Report*, and a database of institutions with an identified CTL. The survey yielded a 38.7% response rate, with a majority of respondents representing public, doctorate-granting institutions in the U.S. Survey topics included: (1) nature of programs, services, and topics offered by CTLs; (2) CTL responsiveness to engineering-specific requests; and (3) ways to support and reward engineering professional development.

Most CTLs served one campus and were organized to provide centralized support serving the entire institution. Some respondents also indicated that there were decentralized structures for faculty development, including discipline-specific or interdisciplinary faculty-led committees. In a couple of instances, engineering-specific faculty development centers existed. Overall, the reported frequency of *engineering* faculty development occurred monthly or once/twice per semester.

The *general* types of programs and services offered by CTLs included the following: (1) workshops; (2) individual consultations; (3) classroom observations; (4) orientations; (5) faculty learning communities; (6) administration of internal grants programs; (7) engagement in national projects; (8) faculty fellows; (9) management of grant-funded projects; and (10) teaching circles. Of these, CTL professionals perceived the following programs and services to be of greatest interest to *engineering* faculty: (1) individual consultations; (2) engagement in national projects; (3) orientations; (4) workshops; and (5) administration of internal grants programs.

The *general* types of topics addressed by CTLs included the following: (1) innovative teaching methods; (2) learner-centered teaching; (3) assessment of student learning outcomes; (4) teaching with technology; (5) teaching assistant training; (6) Scholarship of Teaching and Learning; (7) new faculty needs; (8) multiculturalism and diversity; (9) non-tenure track/part-time faculty needs; and (10) teaching under-prepared students. Of these, CTL professionals perceived the following topics to be of greatest interest to *engineering* faculty: (1) teaching with technology; (2) innovative teaching methods; (3) assessment of student learning; (4) teaching assistant training; and (5) learner-centered teaching.

CTL professionals reported that there are specific ways programming is modified for *engineering* faculty and administrators. These include: (1) using the “language of engineering” and STEM best practices in programs, services, and topics; (2) employing a dedicated staff member to focus on engineering-specific issues; (3) providing individual consultations tailored to the specific needs of engineering disciplines; and (4) bringing in outside/expert speakers on engineering-oriented topics. Furthermore, CTLs seek input/feedback from *engineering* faculty and administrators through the following means: (1) ensuring an engineering presence on the CTL advisory board; (2) conducting end-of-program evaluations; (3) engaging in intentional partnerships with engineering faculty on key issues or topics; and (4) gathering input through needs assessments, surveys, and focus groups with engineering colleagues. It was noted that, in some cases, nothing specific is modified for or sought from engineering colleagues.

While most respondents felt that CTLs were responsive to requests for programs, services, and topics, nearly one-third indicated they received requests from *engineering* faculty and administrators that they were unable to offer. Some of the types of unfulfilled *engineering* requests included the following: (1) instructional technology help; (2) assistance in purchasing/training/using laboratory equipment; (3) discipline-specific assessment of learning; (4) grant-writing experience; and (5) K-12 outreach. Furthermore, CTL professionals indicated their perception that the following are additional items of interest to *engineering* faculty and administrators: (1) ABET- and institution-specific issues in assessment of student learning; (2) integration of teaching and research activities; (3) STEM-specific curriculum/instructional design; and (4) intellectual property laws/issues.

According to CTL professionals, there are several ways that administrators at all levels of the institution can support and reward faculty efforts in improving undergraduate engineering education. Ways to support efforts include: (1) allocating dedicated funding for faculty development; (2) providing meaningful support for and collaboration with CTLs; (3) ensuring that teaching and learning is a priority; and (4) being involved in various CTL activities. Ways to reward efforts include: (1) recognizing effective teaching; (2) providing grants for course and curricular innovations; (3) arranging for faculty release time to enhance their teaching; and (4) allocating graduate student talent to provide support for teaching. Some respondents noted that teaching is not/would not be supported or rewarded at their institution in the same manner as discipline-specific research endeavors.

Overview of the Workshop Outcomes

Against the backdrop of findings from the pre-workshop survey of CTL professionals, and in alignment with the project goals, workshop participants were assigned rotating discussion groups for 4 one-hour-long working sessions. Each working session had a facilitator, scribe, and spokesperson, and each group generated answers to focused questions related to the topic of each session. An overview of the working sessions and focused questions is provided below.

1. Faculty development and student learning
2. Faculty development as educators
3. Role of CTLs
4. Role of administrators

In each of the subsequent sections, we describe the questions that arose in the working sessions, and the findings relevant to that session.

Working Session 1: Faculty development and student learning

Identifying ways of using engineering faculty understanding of student learning issues to inform the planning of professional development programs

Questions addressed in this session included:

1. What are student learning issues in engineering?
2. How can engineering faculty insight inform the planning of professional development programs?
3. How can engineering faculty and CTL staff members partner to create learning environments more supportive of all students?

Findings

A summary of findings from this discussion strand includes three main areas: (1) student learning issues in engineering; (2) engineering faculty insights into planning professional development programs; and (3) methods for engineering faculty/CTL partnerships to facilitate supportive learning environments for students.

1. Student learning issues in engineering

Content issues that could be addressed in the classroom include the need for students to be able to solve open-ended interdisciplinary problems, engage in deep learning that leads to retention and transfer of knowledge, apply design skills, integrate knowledge and transfer that knowledge across different courses, work on diverse teams, and develop ethical frameworks for decision-making.

Structural issues inherent in engineering undergraduate education include the adequacy of labs, facilities, infrastructure, and space on campuses to support programs, a lack of diversity in engineering and the ongoing need to appeal to and attract a diverse group of students, and a more in-depth focus on implementation of ABET outcomes.

Student characteristics that impact learning include issues in the students' backgrounds that may make it hard to foster great gains in learning and development. These include lack of motivation for learning; lack of sufficient preparedness in math, science, critical thinking skills, and hands-on/application-oriented learning; and a conflict between the students' real vs. perceived abilities.

Finally, *instructor characteristics* related to student learning include low expectations of students, a rigid teaching style, lack of respect for or knowledge of the interdisciplinary nature of engineering, and a lack of educational training and understanding of appropriate teaching techniques that can foster learning.

2. Engineering faculty insights into planning professional development programs

Engineering “traditions” in the classroom may result in resistance to change and, thus, pose a challenge in planning professional development programs for this faculty group. Nevertheless, faculty in engineering disciplines have a sense of the content issues that may be problematic for students, as well as the strategies that work effectively or don't work for them in the classroom. Thus, there is a need to deliberately engage faculty at various levels of their career to help in the planning of professional development programs targeted to needs at various points of a career lifecycle.

To do so, a new model needs to be considered—one that includes preparing individuals for change, building an awareness of what is happening in the classroom, creating a plan for how to address the issues, and developing the necessary programming for engineering faculty. This can be accomplished through strategies such as implementing faculty surveys, mentoring, focus groups, etc.; taking advantage of faculty experts/expertise; engaging faculty, particularly those who are not already engaged, and leveraging faculty to engage others who are unengaged; using assessment data, analyses, and discussions to develop insights and improve practice; and developing learning outcomes for professional development and tying them explicitly to the needs of engineering faculty.

3. Methods for engineering faculty/CTL partnerships to facilitate supportive learning environments for students

Partnerships are naturally needed between engineering faculty and CTLs because engineering faculty may not be experts in teaching, learning, and assessment, while CTLs have a skillset offered by the staff that can be adapted for and adopted in engineering contexts. CTLs can help by framing ideas to faculty in the context of scholarship and data, and ensuring that those ideas are driven by the professional development needs of the engineering faculty.

Specific strategies for partnerships between engineering faculty and CTLs include instructional development grants; a showcase of faculty accomplishments in teaching-learning; joint attendance by both CTL and experienced faculty in order to gain insights into student learning issues; activities where engineering faculty and CTL colleagues get to know each other; better assessment of student learning through leveraging of CTL resources; an engineering faculty presence on a CTL advisory board; and audit programs, resources, and interventions to determine when and how support for engineering faculty is needed.

Working Session 2: Faculty development as educators

Identifying needed supports for development of engineering faculty as educators

Questions addressed in this session included:

1. What kinds of opportunities do engineering faculty members need for lifelong development as educators?
2. How do we motivate engineering faculty to participate in these opportunities and reward them for doing so?
3. What campus partnerships need to be formed or enhanced to support these outcomes?

Findings

A summary of findings from this discussion strand includes three main areas: (1) opportunities engineering faculty need for lifelong development; (2) methods for motivating and rewarding engineering faculty for these opportunities; and (3) campus partnerships needed to support these outcomes.

1. Opportunities engineering faculty need for lifelong development

There is a need for lifelong development of engineering faculty at all stages of a career lifecycle: beginning career, mid-career, and late-career. Some of the specific strategies for *beginning career development* include auditing “superstar” teachers in engineering contexts, working efficiently (e.g., balancing priorities; managing time; seeking mentors), grabbing the “low-hanging fruit” such as the betterment of teaching and a focus on student learning outcomes, getting involved in engineering education organizations (e.g., American Society for Engineering Education), and bridging the gap between content expertise and student learning.

Mid-career development opportunities include having dedicated time for major retooling of courses and curricula (e.g., reduced teaching load), engaging in education as a research problem through grant writing and publications (e.g., Scholarship of Teaching and Learning), and collaborating with colleagues both inside and outside of engineering disciplines.

Finally, *late-career development* opportunities include having senior faculty serve as mentors to junior faculty; providing training on how to mentor; and keeping pace with technology, trends, tools, etc. – something that should reasonably occur throughout the career.

2. Methods for motivating and rewarding engineering faculty for these opportunities

Faculty need real-world, practical experience that can *inform* their teaching, time and technology resources to *enhance* their teaching, and awareness and understanding of the criteria used to *evaluate* their teaching. As such, engineering administrators should allow opportunities for faculty to take teaching-related risks; should be held accountable for their faculty’s development as educators; should provide sustained recognition, showcasing of teaching accomplishments, and support for developing engineering faculty as educators; should include teaching

effectiveness and professional development as part of the standards for evaluating annual reports and promotion and tenure portfolios; and should define the outcomes/goals of what engineering faculty are expected to achieve in terms of teaching and student learning impacts.

3. Campus partnerships needed to support these outcomes

Workshop participants noted that the teaching-learning process is typically a consistent, sustainable revenue stream (e.g., tuition income) and a strategic part of the campus mission. Thus, to ensure the appropriate attention to faculty professional development positively impacts student learning, the following partnerships are needed:

- *Faculty and administration*, to ensure mutual goals are met; *CTLs and administration*, to ensure CTL work is “valued” and “validated”;
- *CTLs and other related “centers” or support/related/academic units*, to promote collaboration and integration of faculty work, Scholarship of Teaching and Learning, etc.;
- *Faculty and CTLs*, to ensure reciprocity of learning relationships, priorities, etc.;
- *Students and CTLs*, to get end-user perspectives and input into programming; and
- *Multi-campus and external stakeholder (e.g. employer) collaborations*, for synergy, feedback, leveraging, etc.

Working Session 3: Role of CTLs

Outlining strategies for leveraging resources at CTLs to enhance undergraduate engineering education

Questions addressed in this session included:

1. What kinds of collaborations between CTLs and engineering faculty would have the most positive impact on undergraduate engineering education?
2. How can engineering faculty, administrators, and CTL directors promote collaborations between CTLs and engineering faculty?
3. How can CTLs from multiple institutions work together to meet common challenges in improving undergraduate engineering education?

Findings

A summary of findings from this discussion strand includes three main areas: (1) collaborations that would have the most impact on undergraduate engineering education; (2) methods for promoting collaborations between CTLs and engineering faculty; and (3) methods for CTLs from multiple institutions to work together.

1. Collaborations that would have the most impact on undergraduate engineering education

Collaborations can occur on a continuum from informal to formal and can be either group or individual in nature. Examples of *informal collaborations* include investigations in a classroom based on consultation, targeted workshops in which faculty bring something to work on and leave with a tangible project, and mentor work with groups of several people. Examples of

formal collaborations include CTL providing interventions designed and implemented at the program level using data from student evaluations and learning outcomes to inform professional development activities; CTL working with faculty to engage in systemic educational research on promising pedagogic practices; CTL generalizing professional development to a variety of disciplines, including engineering; and when CTL partnering with engineering faculty on grant proposal development for teaching-learning projects

Group functions in collaboration include continuing education seminars and book/discussion groups; long-term working groups categorized by faculty interests or needs (e.g. teaching large classes); and curricular or course redesign. *Individual functions* include mentoring and maintaining an ongoing relationship with individual faculty members (in this context, the CTL professional serves as the mentor), being a consultant for a short-term relationship, being a scholarly collaborator, and providing support for assessment of student learning.

2. Methods for promoting collaborations between CTLs and engineering faculty

Collaborations can be promoted through communication and recognition. *Communication strategies* include marketing and advertising, changing the connotation that faculty development is meant to be a “punishment” or “remediation” for faculty, using testimonials of positive results from CTL collaborations, providing confidential consultations, providing faculty-led seminars, and building a database and network of “who does what” in engineering education on campus (and elsewhere).

Recognition strategies include awards for faculty who engage in professional development, designation as “faculty scholars” in educational research, formal recognition of the strategic importance of CTLs and their impact on faculty development and student learning, documentation of professional development activities, and helping with the evidence associated with promotion and tenure activities for faculty.

3. Methods for CTLs from multiple institutions to work together

CTLs from multiple institutions can work together through by national networks and intentional collaboration. *National networks* include the American Society for Engineering Education, the Professional and Organizational Development Network, and the Center for the Advancement of Scholarship on Engineering Education.

Intentional collaborations between CTLs include developing resources and tools on teaching and assessment, developing a group of workshops that can be offered jointly and electronically, sharing education or engineering education graduate students across and among institutions for teaching and curricular innovation, and joining together and submitting grants that address large-scale engineering education initiatives.

Working Session 4: Role of administrators

Preparing recommendations for how engineering administrators can support educational innovation and professional development

Questions addressed in this session included:

1. How can university and school of engineering administrators support and recognize educational innovation and professional development?
2. How can CTLs help administrators accomplish their agenda?
3. What types of teaching and learning outcomes would be considered appropriate to include in promotion and tenure dossiers?

Findings

A summary of findings from this discussion strand includes three main areas: (1) methods for administrators to support and recognize educational innovation and professional development; (2) methods for CTLs to help administrators accomplish their agenda; and (3) types of teaching and learning outcomes appropriate for inclusion in promotion/tenure dossiers.

1. Methods for administrators to support and recognize educational innovation and professional development

Educational innovation and professional development can be recognized by administrators through both *financial* and *policy/culture* supports.

Financial supports include travel funds, funds for teaching assistants, staffing resources within the CTL that have a connection to engineering education, resources for new faculty (e.g., startup packages) and mid-career faculty to improve teaching, and financial rewards for teaching-related accomplishments (e.g., teaching awards).

Policy/culture supports include aligning the mission of the institution with the mission of the department and innovation in teaching; providing leadership to curricular change; keeping professional development activities front-and-center on the agendas of appropriate committees; “counting” educational research grants and publications for tenure and/or promotion; making teaching a clear part of written documentation for merit pay, promotion, tenure, etc.; and ensuring that faculty who are promoted/tenured are, in fact, good teachers (in addition to being good researchers).

2. Methods for CTLs to help administrators accomplish their agendas

CTL professionals need to establish relationships with engineering administrators, typically defined as deans and department chairs. In doing so, CTL professionals can ask about the engineering unit’s mission and ways the CTL can support that mission, including identifying the types of teaching-related performance metrics valued by the engineering unit.

CTLs can also help administrators by providing talking points about abilities and accomplishments of the CTLs; providing professional development programs for administrators; aligning CTL programs with goals of administrators; providing literature research support, sometimes through a graduate student; supporting faculty success in promotion and tenure; and

building CTL-administrator contact into a variety of formal and informal institutional structures (e.g., CTL representative serving on appropriate engineering unit committees).

3. Types of teaching and learning outcomes appropriate for inclusion in promotion/tenure dossiers

In many ways, teaching and learning outcomes are similar to the outcomes for discipline-specific research including peer-reviewed publications, conference publications, evidence of teaching effectiveness, evidence of learning growth, grants, new course development documentation, and evidence of the impacts of teaching and learning within and outside of the university.

The teaching portfolio was noted as an appropriate vehicle to document, reflect, and organize teaching-related activities of faculty. Items in such a portfolio would include a teaching philosophy that is informed by the scholarship of the field, student accomplishments, student evaluations, documentation of new things tried in the classroom, peer observation program documentation, and a description of service on policy committees regarding teaching and learning.

Recommendations for CTLs, Engineering Faculty, and Engineering Administrators

There are several overarching recommendations for CTLs, engineering faculty, and engineering administrators that emerge from the summary of workshop discussion strands. These include the need to: (1) leverage partnerships and communication between CTLs and engineering faculty, administrators, and students; (2) enhance teaching effectiveness, including how is it defined, measured, developed, practiced, used, rewarded, and supported; (3) identify and use promising teaching and learning practices that are evidence-based; (4) promote a culture change for valuing teaching and learning in engineering disciplines; (5) organize professional development for faculty that is targeted to career lifecycle needs; (6) help faculty become more efficient in their teaching; (7) facilitate multi-institutional collaborations to support scalable and sustainable professional development opportunities across campuses; and (8) ensure the ongoing assessment of students, learning outcomes, courses, programs, and related items.

1. Leverage partnerships and communication between CTLs and engineering faculty, administrators, and students

An acknowledgment of the reciprocal relationships between CTLs and engineering stakeholders (faculty, administrators, and students) is paramount before true partnerships and ongoing communication can commence. CTLs can provide general teaching-learning expertise, customized to engineering-specific contexts; in turn, CTLs can learn from the educational innovations in engineering to inform their own growth, development, and ability to translate engineering-specific teaching-learning approaches to other disciplines on campus. To do so, however, engineering stakeholder needs must be communicated to CTLs and, in turn, CTL resources and capabilities must be communicated to engineering stakeholders. Leadership by CTLs and engineering administrators must be mutually-supportive and aligned around institutional goals.

2. Enhance teaching effectiveness, including how is it defined, measured, developed, practiced, used, rewarded, and supported

Clear expectations of teaching effectiveness must be established for engineering faculty, and ways to measure its effectiveness (e.g., peer review of teaching; teaching portfolio; end-of-course evaluations) need to occur. Engineering administrators and CTLs can collaborate to provide professional development opportunities to faculty that draw upon well-researched and –documented engineering educational practices. This also extends to the need to foster a culture of experimentation, innovation, and appropriate risk-taking in the teaching-learning process. Ways to reward and recognize outstanding teaching and learning achievements, coupled with ongoing support—in terms of funding, release time, and encouragement for teaching effectiveness—is needed.

3. Identify and use promising teaching and learning practices that are evidence-based

There is an ongoing need to help translate engineering educational research into instructional practice, something that CTLs in partnership with engineering stakeholders are poised to facilitate. This includes the ability to recognize the engineering-specific and STEM-dominant teaching and learning practices that have been established as effective, and to modify and incorporate the evidence-based learning practices of other disciplines within the engineering context, as appropriate. Engineering administrators can work with CTLs to encourage involvement of faculty in engineering-oriented teaching associations and organizations (e.g., American Society for Engineering Education), and to help faculty conceptualize, implement, evaluate, and disseminate their own promising practices in engineering education through endeavors in the Scholarship of Teaching and Learning. Two recent National Research Council Workshops on Evidence-Based Promising Practices in STEM Undergraduate Education have begun to organize and synthesize the body of knowledge. See Fairweather (2008) for an excellent summary.

4. Promote a culture change for valuing teaching and learning in engineering disciplines

Schools of engineering have long-valued faculty discovery and scholarly productivity in the domains of discipline-specific research. There is a need to similarly value engineering-oriented educational research and peer-reviewed dissemination in reward, recognition, and advancement opportunities. To accomplish this, promotion and tenure guidelines need to be reviewed and revised to reflect faculty contributions to the engineering education process—ranging from student mastery of learning outcomes, participation in assessment and accreditation processes, and participation in teaching-learning research activities. Further, alternative career and faculty appointment structures (e.g., Teaching Professors; lecturers) need to be considered in order to emphasize the importance of teaching in the engineering school's mission.

5. Organize professional development for faculty that is targeted to career lifecycle needs

Engineering faculty have unique needs for their professional development at various stages of their career lifecycle. Thus, CTLs can work with engineering administrators and faculty to assess needs, design and implement appropriate interventions, and evaluate effectiveness at

multiple junctures of a faculty member's career. Considerable attention should be provided to early-career faculty in equipping them with the confidence, tools, and resources to be successful teachers—primarily since such faculty may not have been sufficiently prepared to identify and incorporate engineering-oriented pedagogical practices as part of their doctoral-level training. For mid- and later-career faculty, attention to improving and mastering teaching approaches, and becoming mentors to junior faculty, is also needed. Engineering administrators and CTLs can work together to provide appropriate interventions that are consistent with faculty needs, institutional mission, and available resources, and to encourage lifelong learning and professional development for all engineering faculty.

6. Help faculty become more efficient in their teaching

In most engineering contexts, faculty are expected to engage in discipline-specific research and discovery; teach undergraduate and graduate engineering courses, including associated duties of advising, assessment, and curriculum development; and provide service to the campus, community, and profession. Profound opportunities exist to leverage CTL expertise in order to help faculty become more efficient in their teaching—specifically as it relates to providing relevant and accessible consultations, workshops, and other interventions aimed at speeding up the acquisition and implementation of evidence-based pedagogical practices that can make an impact on student learning. Additionally, by providing engineering faculty with efficient means to strengthen their teaching, this potentially makes it possible for faculty to have the time to meet the other requirements of their work portfolio. In doing so, there is also greater likelihood of having faculty see the value in working with CTL colleagues, which may lead to an ongoing, sustained relationship between CTLs and engineering faculty.

7. Facilitate multi-institutional collaborations to support scalable and sustainable professional development opportunities across campuses

There is considerable need for CTLs to coordinate, broker, and package on behalf of engineering faculty a network of professional development opportunities from multiple institutions. This also includes the identification of local, campus-specific sources of strength in engineering education that can be leveraged by faculty at other institutions to enhance their effectiveness. This requires the use of faculty subject-matter-experts from across the country (and, indeed, even around the globe) to make promising practices in engineering education scalable to a wider audience. Technology can be leveraged to provide just-in-time, accessible, relevant, and sustainable interventions for engineering faculty. Large-scale educational research projects, collaborations on grants for teaching-learning purposes, and sharing of best practices in teaching and learning can also occur.

8. Ensure the ongoing assessment of students, learning outcomes, courses, programs, and related items

One principal goal of the teaching-learning process in engineering is student mastery of learning outcomes. Thus, there is a need to understand student learning issues and barriers to their success, especially as it relates to difficulty in mastering often-demanding concepts in engineering, science, and mathematics. CTLs can work with engineering administrators and

faculty to establish learning outcomes, develop and implement appropriate educational interventions to ensure student success in achieving the outcomes, and then assess and evaluate the level of effectiveness in student achievement of the outcomes. Further, course- and program-level assessments can be structured to provide feedback to students, faculty, administrators, CTL professionals, accreditors, and others. Finally, alignment of continuous improvement processes with enhancements to teaching-learning is an area where greater partnerships between CTLs and engineering schools can continue to be developed and sustained.

Conclusion

As shown in this report, each of the principal goals of the workshop was met, as follows:

1. To outline strategies for leveraging resources and expertise at existing CTLs to enhance undergraduate engineering education;
2. To identify programs, support, and resources from CTLs appropriate for engineering faculty to enhance their lifelong development as educators;
3. To identify ways to inform the planning of professional development programs by utilizing faculty insight into student learning issues and difficulties with content; and
4. To prepare recommendations for how engineering administrators could support and recognize educational innovation and professional development through a partnership with CTLs.

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Dissemination

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Russ Pimmel, Program Director
Division of Undergraduate Education, National Science Foundation,

Advisory Board:

Lori Breslow, Director
Teaching and Learning Laboratory
Massachusetts Institute of Technology

Richard Layton, Associate Professor of Mechanical Engineering
Director, Center for the Practice and Scholarship of Education
Rose-Hulman Institute of Technology

Thomas Litzinger, Professor of Mechanical Engineering
Director of the Leonhard Center of the Enhancement of Engineering Education
Penn State University

Karl Smith, Cooperative Learning Professor of Engineering Education
School of Engineering Education
Purdue University
And Morse-Alumni Distinguished Teaching Professor and Emeritus Professor of Civil
Engineering
University of Minnesota

Sheryl Sorby, Director, Engineering Education Innovation Research Group
Director, Solid Mechanics Area Teaching and Learning Laboratory
Michigan Technological University

Keynote speaker: Leah H. Jamieson
John A. Edwardson Dean of Engineering, Purdue University
Co-chair, *ASEE Report on Creating a Culture for Scholarly and Systematic Innovation in
Engineering Education*

Workshop panelists:

Moderator: Pratibha Varma-Nelson, Professor of Chemistry, Executive Director, Center for
Teaching and Learning, Indiana University-Purdue University Indianapolis
Panelists: Russ Pimmel, Program Director, National Science Foundation; Sarah Rajala, Dean of
Engineering, Mississippi State University; Terrence Freeman, Engineering Science
Coordinator, Saint Louis Community College; Gary Gabriele, Dean, College of
Engineering, Villanova University; and Michael Loui, Professor, Electrical and Computer
Engineering, University of Illinois at Urbana-Champaign.

Workshop participants:

See project website at <http://ctl.iupui.edu/projects/NSF/> for complete listing)

IUPUI CTL Project Personnel:

Sharmin Kent, Events Coordinator
Krishna Suresh Patel, Events Coordinator
Adam Parker, Webmaster