Development of Graduate Programs in Engineering Education

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Abstract

Long-term and sustainable engineering education reform requires a pipeline for educating future engineering faculty and professionals interested in pursuing careers in K-12 teaching and administration. Purdue University is evaluating the development of new M.S. and Ph.D. degree programs in engineering education to meet these very needs. It is envisioned that students with Bachelor of Science degrees in engineering and other technical fields will be eligible to participate in the M.S. and Ph.D. programs. These programs will combine advanced courses in engineering and education with research in engineering education. Graduates of such programs will be well-positioned for faculty careers at the K-12, community college, or university level as well as a variety of other careers. Proposed criteria for admission into the M.S. and Ph.D. engineering education programs, descriptions of the programs and program coursework, and anticipated job opportunities for graduates of such programs are discussed.

Vision for Research and Discovery in Engineering Education

The call for engineering education reform is driving the need for the establishment of the field of engineering education as a scholarly endeavor. This call for reform is exemplified in the 1994 joint project report on *Engineering Education for a Changing World* by the Engineering Deans Council and Corporate Roundtable of the American Society for Engineering Education[1], the 1995 Report by the Board on Engineering Education of the National Research Council[2], and the recent call for change by the National Academy of Engineering (NAE) leadership[3]. The other significant development has been the adoption by the Accreditation Board for Engineering and Technology (ABET) of Engineering Criteria 2000 (EC 2000), a new set of program accreditation standards that replace the former focus on counting credits with an emphasis on formulating and assessing educational outcomes. These standards have intensified an interest in assessment reflected in a number of papers on the topic in engineering education journals. Moreover, as faculty members have come to recognize that changes in pedagogy will be needed to achieve the varied outcomes specified in EC 2000, many of them have undertaken the development and assessment of new methods designed to meet those outcomes. Thus, while EC 2000 does not

directly require the scholarship of teaching, its adoption has led to a substantial increase in the number of engineering faculty members engaged in this form of scholarship, which has in turn led the engineering education journals to increase their sizes to accommodate dramatic increases in the number of papers submitted.[4]

The National Science Foundation has supported educational scholarship in engineering since the late 1980's through the Division of Undergraduate Education and the Engineering Education Coalitions program. Today, NSF support for engineering related education reform is in excess of $200M per year. Such support "has increased the status of educational research in faculty performance reviews, improved its quality by demanding appropriate assessment of results, attracted additional engineering professors into the arena, and increased collaborations between engineering professors and professors in disciplines like education and psychology."[4]

Scholarly Activities in Engineering Education

In *Scholarship Reconsidered*[5], Boyer noted that mention of being "scholarly" brings to mind individuals involved in publication of basic research. And yet he notes that the term research only entered the vocabulary of American higher education in 1906. Until then, scholarship brought to mind a variety of different forms of creative work. Boyer called for a return to a broader definition of scholarship, which included the scholarship of discovery, the scholarship of integration, and the scholarship of teaching. He concluded that knowledge is acquired through research, through synthesis, through practice, and through teaching.

Within the field of engineering education, the scholarship of discovery, the scholarship of integration, and the scholarship of teaching are all relevant and seamlessly bound. To focus only on teaching is to trivialize the work and contributions of leaders in this field and the potential for the field to catalyze significant engineering education reform. While the term scholarship of teaching has come to mean more than the knowledge gained from preparing for and participating in one's classes and the earning of a reputation for excellence in the classroom, it does not reflect the breadth of scholarly activity that occurs under the engineering education umbrella. These scholarly activities include but are not limited to:

- Quantitative and qualitative research on student learning and learning environments focusing on the abilities and skills engineering and pre-engineering students need to develop to be successful at each stage of their academic careers and beyond.
- Development, implementation, and assessment of new instructional models, materials, and learning environments.
- Dissemination of research results to a wide variety of audiences including engineering colleagues; math, science, and technology educators; and policy makers.
- Preparation of the next generation of faculty and professionals wishing to pursue work in the field of engineering education.
- Seeking and securing funding to support research activities.

Why in Engineering?

The history of efforts to bring the scholarship of teaching and learning of science, engineering, and mathematics into the content departments has been plagued the question "Why can't this work be done in the School of Education?"

Education research done by faculty in the Schools of Education tends to focus on the problems of teaching and learning in K-12 classrooms. Research in chemistry education, for example, has provided useful insight into the problems children have understanding heat and temperature or the problems high school students have when trying to master the task of balancing a chemical reaction. While this research is potentially useful for those who teach in the elementary, middle and high schools in the U.S. and abroad, it does not necessarily address the problems that faculty face when teaching sophisticated topics in science, engineering, and mathematics at the university level.

For examples of research that does address sophisticated topics focused at the university level, consider several projects recently completed by graduate students working towards a Ph.D. in chemical education at Purdue University in the Department of Chemistry. One graduate student completed a Ph.D. based on interviews that probed the conceptual understanding of thermodynamics by advanced undergraduates and graduate students in the Department of Chemistry. Another student built on this foundation to examine the problems that students in chemistry and chemical engineering encounter when studying quantum mechanics at the junior level. Although this work used methodology similar to the used by colleagues in the School of Education, it required a basic understanding of physical chemistry that is far beyond that commonly found among either faculty or graduate students in education.

Engineering education as a field of scholarly activity needs to be pursued by engineers. Because they are the heavy users of mathematics, science, and technology in problem solving and design contexts, engineers possess knowledge, understandings, and skill sets that characterize what is needed for success beyond school in the 21st century. Therefore, engineers are well positioned to take a leadership role in renewing, diversifying, and nurturing a cadre of talented leaders to guide the expansion of engineering education in K-12 and improve student learning across K-16.

Current Graduate Programs and Training in Engineering Education

While institutions are beginning to move toward developing Engineering Education programs and several engineering education centers have been developed (see Appendix I), no formal or institutionalized graduate programs in engineering education exist.[a] While no formal programs currently exist, graduate student are currently earning graduate degrees linking engineering and education. The Educational Research Methods (ERM) Division sponsors an Apprentice Faculty Grant (AFG) program annually for graduate students and new faculty who are interested in a career in educational research related to engineering. This program has attracted many students who are involved in engineering educational research and has provided anecdotal evidence of

[a] Purdue University is evaluating the development of a School of Engineering Education which will offer M.S. and Ph.D. programs in engineering education.[6] Virginia Tech is developing a Department of Engineering Education that will offer graduate courses in engineering education.

how this is being accomplished nationally. Most of these students and graduates come from institutions that were part of the NSF Coalitions or that currently have an Engineering Education Center. The majority of graduate students who receive degrees through a college of engineering are from those where the subject matter loosely fits the department's traditional research areas. For example, Industrial Engineering has had studies of a user design where the users were students and/or teachers as well as studies on teaming in education. A significant number of students pursue engineering education from colleges of education in areas such as education psychology, technology, math education, science education or higher education. Such students often come from a background in engineering or science.[7]

A Vision for Graduate Degree Programs in Engineering Education

As mentioned previously, Purdue University is evaluating the development of M.S. and Ph.D. programs in engineering education. What follows is a "snapshot" of Purdue's current vision for these programs.

Graduate programs in engineering education should be designed to meet the needs of students with a broad range of backgrounds and interests. Engineering education faculty will work with students to develop a plan of study that best meets their individual academic needs and career goals. Possible graduate degree paths for students having earned Bachelors of Science degrees in engineering and in other technical fields[b] are illustrated in Figure 1.

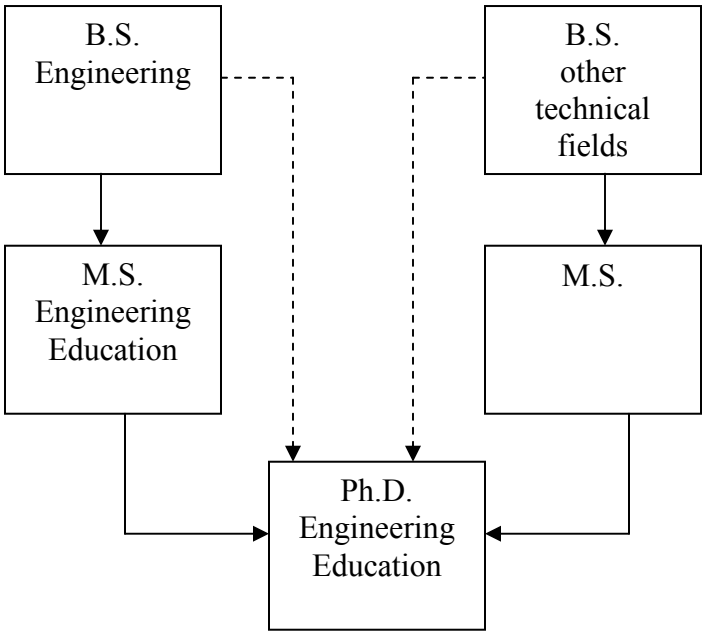

Figure 1. Proposed Graduate Degree Programs in Engineering Education

[b] Technical fields other than engineering: agriculture, biology, chemistry, computer science, math, math education, physics, science education, technology

M.S. (BS-technical field other than engineering)
M.S. in Engineering Education (BS-Eng)
M.S. degree programs will provide students with an understanding of engineering principles and applications and the pedagogical techniques required to teach engineering principles and applications. The master's programs will be designed for students who are interested in pursuing careers in community college or K-12 education (including teachers or math/science coordinators for school districts) or in obtaining doctorate degrees in engineering education. Students pursuing master's degrees may also be interested in careers in corporate training. Approximately 18-24 course credit hours and a master's thesis are required for the master's degree. Students pursuing master's degrees will be advised by a graduate committee consisting of three engineering faculty members, at least one of which is from the School of Engineering Education.

Ph.D. in Engineering Education
To obtain a Ph.D. in engineering education, students must i) complete 36-48 course credit hours beyond those achieved for the bachelor's degree, ii) pass a cumulative exam in a traditional engineering content area, iii) write and defend an original proposal for research in engineering education, and iv) conduct research for, write, and defend a Ph.D. dissertation on an engineering education topic. A master's degree is not required as part of the Ph.D. program, although credits earned in master's programs will often count towards the Ph.D. requirements.

This degree program will be designed to prepare the recipient for a career in engineering education at the undergraduate or post-graduate level. Students with expertise in qualitative and quantitative research methods will be well-positioned to work for K-12 schools, community colleges, and universities as well as other nonprofit and for-profit organizations (including testing organizations, foundations, governmental organizations, etc.) as faculty members, researchers, assessment and accreditation coordinators, policy makers, program officers, curriculum designers, corporate trainers, and directors of teaching/learning centers, diversity programs, or outreach programs.

Students pursing a Ph.D. in engineering education will be advised by a graduate committee consisting of at least four graduate faculty members, three faculty members from engineering (at least one from the School of Engineering Education) and at least one faculty member from outside of engineering (e.g. education, psychology, etc.).

Criteria for Admission
Table 1 lists the elements of the criteria for admission to the graduate programs.

Table 1. Criteria for Admission to Engineering Education Graduate Programs

Applicant Profile	Elements of Admission Criteria	Conditions of Admission
B.S. degree in engineering	• Undergraduate GPA • GRE scores • Letters of recommendation • Personal statement	As a condition of admission, the applicant may need to complete 9 credit hours of graduate-level course work as recommended by the graduate committee.

B.S. degree in a technical field other than engineering	• Undergraduate GPA • GRE scores • Letters of recommendation • Personal statement	As a condition of admission, the applicant may need to complete additional credit hours of undergraduate courses in basic science, mathematics (through differential equations will be required), and/or engineering science as recommended by the graduate committee. The courses will not be available for use in the master's degree plan of study.

Core Graduate Courses in the School of Engineering Education

Table 2 lists potential core courses that would be offered to students in the graduate program.

Table 2. Potential Core Engineering Education Graduate Courses

Potential Required Courses (3 credits unless otherwise noted)	Course Level	Collaborating Faculty
Overview of Engineering Sciences I	EED 5XX	Engineering faculty
Overview of Engineering Sciences II	EED 5XX	Engineering faculty
Supervised Teaching Practicum I	EED 5XX	Engineering and education faculty
Supervised Teaching Practicum II	EED 6XX	Engineering and education faculty
Applications of Engineering	EED 5XX	Engineering faculty
Pedagogical Issues for Teaching Engineering Science	EED 6XX	Engineering and education faculty
Teaching and Assessing Engineering Design	EED 5XX	Engineering and education faculty
The Teaching of Engineering Problem Solving: Insights and Issues	EED 5XX	Engineering and education faculty
Assessment Methods in Engineering Education	EED 5XX	Engineering, education, and statistics faculty
Applied Qualitative and Quantitative Research Methods in Engineering Education	EED 6XX	Engineering, education, and statistics faculty
Master's Thesis Research	EED 599	Engineering and education faculty
Ph.D. Thesis Research	EED 699	Engineering and education faculty
Special Problems in Engineering Education (1-6 credits)	EED 590	Engineering and education faculty
Special Topics in Engineering Education	EED 595	Engineering and education faculty

In addition, 500- and 600-level elective courses will be developed. These courses may be co-developed and/or co-taught with faculty from engineering, education, psychology, computer science, and technology departments. Possible topics to be included in these courses are:

- TEAMING IN THE ENGINEERING CLASSROOM
- SERVICE LEARNING AND ENGINEERING
- PROMOTING DIVERSITY IN ENGINEERING EDUCATION
- ENGINEERING CURRICULUM AND CURRICULAR MATERIALS DEVELOPMENT (UNDERGRADUATE/GRADUATE)
- INSTRUCTIONAL STRATEGIES USING COMPUTERS
- ENGINEERING EDUCATIONAL LITERATURE AND LITERATURE REVIEW
- EDUCATIONAL METHODS IN ENGINEERING
- DESIGNING ENGINEERING OUTREACH PROGRAMS
- TEACHING ENGINEERING TO K-12

- ENGINEERING CURRICULUM AND CURRICULAR MATERIALS DEVELOPMENT (K-12)
- THE SCIENCE OF LEARNING ENGINEERING: INSIGHTS AND ISSUES
- MOTIVATION OF ENGINEERING STUDENTS
- TEACHING TECHNICAL COMMUNICATION
- THE NATURE OF SCIENCE IN TEACHING ENGINEERING

Summary/Concluding Remarks

Long-term and sustainable engineering education reform requires a pipeline for educating future engineering faculty and professionals interested in pursuing careers in K-16 teaching and administration. There are currently no formalized programs to produce such professionals within engineering. Students who seek to meet this demand must either navigate traditional engineering programs while they integrate educational components or leave engineering and pursue an education degree with an engineering context.

The time is right for engineering programs to acknowledge engineering education as a legitimate area for scholarship and discovery through the creation of graduate programs in engineering education. ABET's EC 2000 has intensified the interest in assessment and evaluation. The pace and demand for educational reform is increasing to address the continued underrepresentation of women and minorities, new and emerging technologies and fields and globalization. NSF's support for engineering education has continued to rise through funding of educational programs and linkages between research and education

The response to these pressures and opportunities has been a dramatic rise in the number of engineering education centers nationally. While these centers provide valuable resources for faculty and can be a catalyst for scholarly work, they do not address the issue of the pipeline. Purdue University has begun planning for new M.S. and Ph.D. degree programs in engineering education where students with Bachelor of Science degrees in engineering and other technical fields will be eligible to participate in the M.S. and Ph.D. programs. These programs will combine advanced courses in engineering and education with research in engineering education and create a pipeline of engineering faculty and professionals who are be well-positioned for leadership in engineering education at the K-12, community college, or university level as well as a variety of other careers.

We are aware of the challenges to establishing engineering education as a main thrust of scholarly activity. However, the need for engineering education reform is great and only engineers, as heavy users of mathematics, science, and technology, have the understanding of the study and practice of engineering to drive this reform across K-16 and graduate programs.

References

1. ASEE Deans Council and Corporate Roundtable, *Engineering Education for a Changing World,* Washington, DC: American Society for Engineering Education, October 1994.

2. National Research Council's Board on Engineering Education, *Engineering Education: Designing an Adaptive System,*

National Research Council Report, Washington, DC: National Academy Press, 1995.

3. Wulf, William A. and Fisher, George M. C., "A Makeover for Engineering Education," *Issues in Science and Technology,* Spring 2002, www.nap.edu/issues/18.3/p_wulf.html.

4. Wankat, P. C.; R. M. Felder; K. A. Smith; F. S. Oreovicz, "The Engineering Approach to the Scholarship of Teaching and Learning," in M. T. Huber and S. Morreale (Eds.) Disciplinary Styles in the Scholarship of Teaching and Learning, AAHE, Washington, D.C., 217-237, 2002.

5. Boyer, E., Scholarship Reconsidered: Priorities of the Professoriate, Jossey-Bass Publishing, 1997.

6. Katehi, L.; Banks, K.; Diefes-Dux, H.; Follman, D.; Gaunt, J.; Haghighi, K.; Imbrie, P.K.; Jamieson, L.; Montgomery, R.; Oakes, W.; Wankat, P., "A New Framework for Academic Reform in Engineering Education," Proceedings of the 2004 ASEE National Conference, Salt Lake City, Utah, June 2004.

7. Adams, R. and Cummings-Bond, R., "Career Trajectories in Engineering Education – Where are They Now?" Proceedings of the 2004 ASEE National Conference, Salt Lake City, Utah, June 2004.

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APPENDIX I
Established Engineering Education Centers

It appears at this time that no single institution or engineering education center offers graduate programs in engineering education; however, they do contain various aspects of what the M.S. and Ph.D. programs proposed in this paper strive to accomplish.

Arizona State University- *Center for Research on Education in Science, Mathematics, Engineering, and Technology*, (CRESMET), http://www.eas.asu.edu/~cresmet

Mission:

- Bring together individuals, program, and organizations interested in improving K-20 science, mathematics, engineering, and technology education.
- Research, develop, and assess educational theories, curricula, and administrative policies that impact science, mathematics, engineering and technology education.
- Encourage and support wide-scale sharing and implementation of effective approaches to producing a more scientifically and technologically literate populace and more capable science, mathematics, engineering, and technology majors.

CRESMET consists of an Interim Director (Dr. Marylin P. Carlson), two Associate Directors, Business Manager, Administrative Assistant, Director of Assessment and Evaluation, a Student Technical Support/Webmaster, two Graduate Research Assistants. All faculty members who hold a position in the center are tenured through one of the academic departments on campus, not through the center, although this is something that they have discussed. These faculty members do not have a full appointment in the center, they are appointed in their designated departments.

Colorado School of Mines- *Center for Engineering Education* (CEE), http://www.mines.edu/research/cee

Theoretical Framework:

- Discovery – the act of creating new knowledge within a given discipline; traditional view of research on college campuses
- Integration – connects information between different disciplines and areas of knowledge; the act of taking facts and concepts that emerge through separate investigations and linking these facts in a meaningful manner; allows discoveries in one area to inform the discoveries in another area.
- Application – builds upon the scholarship of discovery and the scholarship of integration and focuses on "how can this knowledge be used?"
- Teaching – puts the results of research into action

Practices:

- Educational Research – CEE assists faculty members in establishing an educational research agenda, implementing that agenda, interpreting and using research results, and disseminating the results of their own research.
- Improving Instructional Practices – CEE provides workshops for both faculty and graduate students on the techniques of college teaching, and recent developments in the educational literature. CEE faculty also teach a graduate-level course called "Fundamentals of College Teaching" for doctoral students contemplating a career in academia.
- Outreach Activities – CEE involvement with local elementary, middle, and high schools is anticipated.

Goals:

- Conduct world-class research on teaching and learning in science and engineering.
- Disseminate the results of that research to the engineering education community to increase student learning.
- Support the educational needs of science and engineering instructors at both the K-12 and the college level.

The Office of Teaching Effectiveness began in the early 1990's and became the Center for Engineering as of 2000.
Currently, there are three staff members assigned to the Center- a Director and a Research Associate. Dr. Ruth Streveler, the Director, is classified as Administrative Faculty (non-tenure track position) and the Research Associate is classified as Research Faculty (non-tenure track position). A staff member (15%) also contributes to the Center. There are others associated with the Center (all affiliates) who reside in academic departments, but do not work the Center more than a month a year.

Georgia Institute of Technology- *Center for the Enhancement of Teaching and Learning* (CETL), http://www.cetl.gatech.edu

Mission:

- To lead Georgia Tech to a teaching and learning standard of excellence – fostering, recognizing, and rewarding a community of unparalleled teachers and learners through our commitment to faculty development, assessment, and support.
- To enhance the learning and teaching environment at Georgia Tech by encouraging a fully engaged, sharing community with communication networks, resources, and innovative programs.

The Center's main focus is on faculty and teaching assistant development. They do some research on education and in particular science and engineering education issues. They are not an academic department so faculty can't have the center as an academic home department. The Director, Dr. Donna C. Llewellyn is an adjunct in industrial engineering - her old home department prior to working with the center. The center has the following individuals:

- Director - 100% administrator
- Assistant Director – 100% assigned to the center
- TA coordinator – 50% center and 50% in modern languages (tenure)
- Two full time instructional technology specialists
- A full time "academic professional" - like a research scientist/general faculty member - non-tenure track, to do faculty development and educational research
- A full time administrative coordinator, a part time administrative assistant, and 50% of a computer support person.

The center offers a host of training seminar/courses for graduate students that are now available for credit.

Kettering University- *Center for Excellence in Teaching and Learning* (CETL), http://www.kettering.edu/cetl

Mission:

- Promote a learner-centered educational community
- Encourage and support the teaching-related professional development of all educators
- Archive and disseminate teaching and learning resources
- Coordinate activities for improvement of teaching and learning
- Support innovation and scholarship activities related to teaching and learning and promote educational research
- Provide training for faculty in student outcomes assessment

Facilities:

- A Resource Center that houses CETL's collection of journals, books, videos, and other materials, all available for check-our to members of the Kettering community
- A Computer Resource Center, available for faculty use, with six computer workstations and a collection of education-related software
- A conference room for CETL activities

The Center for Excellence in Teaching and Learning (CETL) has been in existence for about three years and its primary mission is to enhance learner-centered education at Kettering University. It is a small organization

with one secretary and a Director. Dr. Daryl Doyle has a 2/3 appointment as the Director and 1/3 as Professor of Chemistry. His term of office as director is 2 years with the possibility of renewal on a yearly basis after that. It is not possible to be the Director unless you have tenure from one of the academic departments. The goal of CETL is to assist faculty to be better teachers though supporting workshops and travel grants. They have not developed the student involvement of CETL yet but it is one of their goals. They are in charge of the new faculty orientation (1 1/2 day session), recognition of outstanding teaching on campus, peer observation of classes for improvement and not promotion and tenure, and the expanded use of technology in the classroom.

Penn State University- *Leonhard Center for the Enhancement of Engineering Education,* http://www.engr.psu.edu/LeonhardCenter/eec/lc/

Mission:

- To enable the significant enhancements of engineering education that are required to educate students who will become world-class engineers.

Goals:

- Formation of partnerships with Engineering Departments to undertake substantial enhancements of their core curricula and courses.
- Enabling initiatives with College-wide impact such as the integration of engineering ethics and the use of technology in teaching and learning.
- Assessment of the impact of innovative projects on students' intellectual development and development of expertise.
- Faculty development related to teaching and learning.
- Integration of students in the process of change.

Center Projects include, but are not limited to, an Engineering Entrepreneurship Minor, an Engineering Leadership Development Minor (ELDM), Engineering Ethics, and the Leonhard Center Technical Writing Initiative (LCTWI).

The Leonhard Center works closely with the Engineering Instructional Services (EIS) program. The Director of the Center is a tenured faculty member from one of the academic departments, and the Director of EIS is a Ph. D. in Education with a non-tenure track faculty appointment. There are 1.5 staff members and typically 4 or 5 graduate assistants from various parts of the College of Education who assist in instructional design and assessment.

The primary activities of the Center are to foster innovative changes in undergraduate curricula and teaching & learning methods. The center typically provides funding directly to departments for these projects. EIS provides instructional design and assessment expertise to the projects that they undertake with departments. The Center works jointly with EIS in delivering faculty development workshops to assist faculty in enhancing their courses and their teaching skills.

They do not offer a curriculum or graduate education in education.

University of Illinois- *Academy for Excellence in Engineering Education* (AE3), http://ae3.cen.uiuc.edu/

AE3, which began in 1994, is a center for effective teaching and learning within the College of Engineering at the University of Illinois at Urbana-Champaign. In the midst of current concerns that large research universities often ignore teaching, AE3 is a clear example of a commitment to creating strong teachers, well-trained teaching assistants (TAs), and well-prepared, engaged students. AE3 advocates excellence in engineering education specifically through instructor development, course redesign, and learning innovations. Programs such as Fast Start, the National Teaching College, and the Assessment Center are provided to support faculty development. Special programs including the "Learning to Learn" program are also offered to assist student development.

AE3 is made up of faculty, staff, graduate assistants and students from a variety of colleges, departments and academic units: the College of Engineering, the Department of Human Resource Education, and the Office of Instructional Resources are among the contributing units that make AE3 possible.

There are not any tenure-track faculty lines associated with AE3 except for the Director. Dr. Bruce Litchfield directs AE3 as a portion of his responsibilities in the academic programs office, but for several years he did it "in the margins" of his conventional faculty appointment.

In addition to the director (~10-15% of his time), there are two staff persons, Dr. Leslie Crowley, ~ 50% time and Dr. Laura Hahn ~50% time (and funded by the campus Office of Instructional Resources). Also Scott Johnson, an Education Prof., and several engineering faculty, pitch-in with conducting observations, workshops, etc. For more, see http://ae3.cen.uiuc.edu/about_ae3.htm

They do not have a graduate program/curriculum, and strictly speaking, by Illinois standards, they are not a center. Of course there are extensive graduate programs in education in the College of Education, some even deal with college teaching.

University of Washington- *Center for Engineering Learning and Teaching* (CELT), http://www.engr.washington.edu/celt

- Teaching – CELT's instructional services are designed to meet the specific teaching needs of engineering faculty as they improve teaching effectiveness and enhance engineering student learning. CELT collaborates with faculty through seminars or workshops and individually. The most common topics include:
    - Designing (or redesigning) courses, engaging and motivating students, gathering data on student learning, interpreting student ratings, and writing engineering education proposals, articles, and presentations.
- Research – Conducting research that is unique to engineering education, exploring how to more effectively teach the elements of engineering that separate engineering from applied science, and taking a systematic approach to understanding and adapting the large body of existing education research to determine what results may be applicable in engineering classrooms.

CELT consists of a Director, Instructional Consultant, Manager of Program Operations, Affiliate Faculty of Technical Communications, two Research Scientists, two graduate students and four undergraduate students.

University of Wisconsin- *Engineering Learning Center,* http://www.engr.wisc.edu/services/elc/

Mission:

- To serve faculty, staff, graduate students, undergraduate students, and administrators. It is designed to foster effective student-centered teaching and learning within the College of Engineering.

Objectives:

- Provide professional development opportunities and resources for instructors and students.
- Facilitate connections for other units that support teaching and learning.
- Help build a culture of continuous improvement in undergraduate and graduate education.

Three individuals, including a director/adjunct assistant professor and a professor in Mechanical Engineering, lead ELC.