

Rackham Certificate Program in Engineering Education Research

Approved, March 12, 2009

Program conception and objectives

Engineering education is an emerging interdisciplinary field in which scholars apply the methods of educational research to address a variety of issues pertaining to teaching and learning in engineering. Researchers who work in this field typically have formal training in a technical engineering discipline, but they acquire a working knowledge of the principles of education research in an informal way. The recent “Research Agenda for the New Discipline of Engineering Education” (*Journal of Engineering Education*, Oct. 2006, pp 257–261) describes the following five major research areas of the field:

- “What constitutes engineering thinking and knowledge within social contexts, both now and in the future?”
- “How do engineering learners develop knowledge and competencies in context?”
- “How do the instructional culture, institutional infrastructure, and epistemology of engineering educators affect the learning environment?”
- “What is the unique contribution of diverse human talents to the social and global challenges and relevance of our profession?”
- “What assessment methods, instruments, and metrics can be developed and implemented to best inform engineering education practice and learning?”

Besides being relevant on a national scale, these questions are of great interest to the U-M community. Both faculty and graduate students in the College of Engineering have expressed a desire to learn more about the field, and this proposal is to establish a *Rackham Certificate Program in Engineering Education Research* to provide engineering doctoral students with a formal program to learn the skills needed to be proficient in the field.

Background

Interest in the new field of engineering education research is increasing, both on a national and local level. The National Science Foundation (NSF) and National Academy of Engineering (NAE) have new programs in place to support research in engineering education, and the American Society for Engineering Education (ASEE) and its *Journal for Engineering Education* provide high-quality avenues for dissemination. In addition, several colleges of engineering have created formal opportunities for doctoral students to earn cross-disciplinary degrees in engineering education research, and a multitude of institutions have a focus in research in engineering education. At U-M, engineering faculty and staff have conducted their own cross-disciplinary research, and the College of Engineering (CoE) community has been eager to learn about the work of others. Current and recent CoE graduate students have also pursued research in the field and have expressed interest in having a more formal way to learn about engineering education research.

National interest:

- NSF has strengthened and refocused a variety of programs, placing more emphasis on understanding how students learn engineering and on developing methodologies for rigorously assessing education innovations (e.g., EEC – Engineering Education & Centers; CCLI – Course, Curriculum, and Laboratory Improvement; REESE – Research and Evaluation on Education in Science in Engineering; and ROLE – Research on Learning and Education).
- NSF funds several multi-million-dollar national centers that conduct research in engineering education (e.g., the Center for the Advancement of Engineering Education, headquartered at the University of Washington and including Colorado School of Mines, Howard University, Stanford University and University of Minnesota, funded for more than \$12 million; the National Center for Engineering and Technology, a consortium of nine universities and more than fifteen school districts, funded for more than \$10 million; the Center for Integration of Research, Teaching, and Learning which is a partnership between University of Wisconsin, Michigan State University, and Pennsylvania State

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University, funded at more than \$10 million; and VanTH-ERC, Vanderbilt-Northwestern-Texas-Harvard/MIT Engineering Research Center, funded at more than \$21 million).

- NSF has sponsored workshops to help prepare researchers for the cross-disciplinary work required for engineering education research (e.g., Conducting Rigorous Research in Engineering Education; the annual International Conference on Research in Engineering Education; the Engineering Education Research Colloquies; and the Institute for Scholarship on Engineering Education).
- NAE created a major annual award to recognize an innovator in engineering education (the Bernard M. Gordon Prize for Innovation in Engineering and Technology Education) and has published several renowned reports about engineering education (e.g., *The Engineer of 2020: Visions of Engineering in the New Century*; *Educating the Engineer of 2020: Adapting Engineering Education to the New Century*; and *Rising above the Gathering Storm*). These reports are driving research in the new field.
- In 2002, NAE established the Center for the Advancement of Scholarship on Engineering Education (CASEE). One main initiative of CASEE is to build collaborative networks with individuals and colleges exploring issues in engineering education. Currently, there are 26 Research Community Affiliates and 15 Implementation Network Affiliates with CASEE (U-M CoE is a Research Community Affiliate).
- ASEE is a major supporter of research in engineering education. ASEE hosts an annual conference that is attended by almost 3500 engineering educators each year. The Educational Research and Methods Division (ERM) is one of the strongest divisions of ASEE¹, and membership in ERM is growing – there were 970 ERM members in 2001 and 1,226 in 2007.
- The Journal of Engineering Education (JEE), ASEE's main research publication, is a renowned outlet for scholarship and research on engineering education. Based on its high Impact Factor, the journal is ranked #1 in both the Thomson ISI Science Citation Index (in the "Education, Scientific Disciplines" category) and the Social Science Citation Index (in the "Education and Educational Research" category). In 2005, the journal published a special issue on *The Art and Science of Engineering Education Research* and became "a new journal for a field in transition." In 2006, JEE published *The Research Agenda for the New Discipline of Engineering Education*, and the journal continues to provide an outlet for rigorous research in engineering education.
- Several institutions have created departments of engineering education or other formal opportunities for engineering graduate students to study engineering education. Purdue University's School of Engineering Education, established in 2004, offers both a master's and Ph.D. program in engineering education. Virginia Tech's Department of Engineering Education, also established in 2004, offers a Ph.D. in engineering education as well as a graduate certificate in engineering education. Clemson University's Department of Engineering and Science Education, established in 2007, offers a graduate certificate in engineering and science education, and it is finalizing plans for a Ph.D. program as well. Other institutions also have programs in engineering education: Utah State University's Department of Engineering and Technology Education offers a master's degree in engineering and technology education as well as a Ph.D. degree in education (curriculum and instruction), Carnegie Mellon University has the Program for Interdisciplinary Education Research for Ph.D. students, Tufts University offers both a master's and Ph.D. in Mathematics, Science, Technology, and Engineering Education, and the School of Education at Colorado State University offers an undergraduate major in Engineering Science/Engineering Education.
- The University of Washington and Ohio State University both have a chaired professorship in Engineering Education, and several colleges of engineering have campus-based centers that support research in engineering education (e.g., the Center for Excellence in Learning and Teaching at University of Washington; the Center for Research on Education in Science, Mathematics, Engineering, and Technology at Arizona State University; the Center for Engineering Education at the Colorado School of Mines; and Northwestern Center for Engineering Education Research).

¹ The Director of CRLT North is currently the Chair of the ERM Division of ASEE.

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Local faculty interest:

- Several U-M engineering faculty have conducted their own scholarly projects in engineering education, and in many cases they have partnered with faculty in the School of Education. They have presented their work in many national venues, including 18 presentations at the 2006 ASEE conference and 17 at the 2007 ASEE conference. More than 50 faculty and graduate students from across the university attended the summit “Educating a STEM Workforce” which highlighted work by U-M faculty in the area. In October 2008, 19 projects were featured during CRLT North’s Third Annual Research and Scholarship in Engineering Education poster session, and more than 100 members of the CoE community attended.
- At least one funded NSF project includes U-M researchers (including graduate students) from both engineering and education (i.e., “A Holistic Assessment of the Ethical Development of Engineering Undergraduates”, funded for more than \$850,000). Several recent proposals submitted to NSF feature similar collaborations (e.g., “Who Persists in STEM Majors and Why: A Mixed Method Approach” (still under consideration); “Preparing Scholars of STEM Professional Practice: The Learning Sciences at Michigan” (not funded); “The GK-12 + University of Michigan Partnership Project Where do I start?” (not funded); “How Women Make the Decision to Enter Math, Science and Engineering Careers” (not funded); and “The M-STEM Academy” (still under consideration)).

Local graduate student interest:

- Recent U-M engineering graduate students have pursued research in the field. In 2008, a graduate from the Industrial and Operations Engineering department wrote her dissertation on *Empirical Studies on Freshmen Student Retention*. The dissertation committee included faculty in engineering and the School of Education. Two U-M engineering alum were awarded grants from the Engineering Education & Centers Division of NSF (a 2003 Ph.D. earned one of only six CAREER awards funded by the division for her proposal *Colleges of Engineering as Learning Organizations: Implications for Student Intellectual Development*; and a 2006 Ph.D. was awarded a grant for his proposal *Using Constructivist Teaching Strategies in Engineering Education: Gauging the Impact on Student Learning and Retention*).
- Graduate students (including members of the student chapter of the ASEE, students enrolled in the 3-credit course ENG 580: Teaching Engineering (taught by Dr. Susan Montgomery), Engineering GSI Mentors, and others) have increasingly expressed interest in having a more formal way to learn about engineering education research. Such students often seek career advice and assistance with their own scholarly projects in engineering education, and many of them have gone on to academic careers.

Program description

Consistent with the university-wide requirements for all Rackham certificate programs, the *Rackham Certificate Program in Engineering Education Research* will require 15 credit hours of coursework. The program – designed in consultation with faculty and department chairs from CoE and the School of Education (including both the Center for the Study of Higher and Postsecondary Education and Education Studies) – comprises four core courses and one elective, as described subsequently. When appropriate, students may request a variation to the program requirements (i.e., based on an individual’s background and interests, courses other than those specifically listed may be a better fit for some students).

Course syllabi for the core courses are attached to this proposal. The courses in the program are regularly taught classes that already exist, and students may take them in any order (as long as prerequisites are satisfied). Students will plan their program of study and select the elective course for the certificate in consultation with both the engineering program advisor and the program advisor from the School of Education (Christopher Quintana). Further, it is a requirement of the certificate that students engage in an engineering education research project – for most students, this will take the form of a course project, and some students may even complete a dissertation that incorporates engineering education research. The program advisors will assist in identifying a course of study to ensure that at least one of the courses includes a research component.

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Required Coursework (12 credits)

- **ENG 580. Teaching Engineering**

Prerequisite: Graduate standing. 3 credits, offered every fall term

This course is aimed at doctoral students from all engineering disciplines interested in teaching. Topics include educational philosophies, educational objectives, learning styles, collaborative and active learning, creativity, testing and grading, ABET requirements, and gender and racial issues. Participants prepare materials for a course of their choice, including course objectives, syllabus, homework, exams, and a mini-lecture.

***Due to high student demand, this class is offered every fall term. ***

- **One of the following courses on quantitative methods:**

- **EDUC 795. Quantitative Methods for Non-Experimental Research**

Prerequisite: EDUC 794 or equivalent. 3 credits, offered every winter term

This is a field-based intermediate-level course in research methods that focuses on non-experimental research. The course emphasizes application of statistical concepts to current educational problems and focuses on regression-based methods, including path analysis and analysis of covariance.

It is expected that engineering doctoral students will satisfy the prerequisite requirements through "equivalent" courses taken previously.

- **EDUC 793. Introduction to Quantitative Methods in Educational Research**

Prerequisite: Graduate standing at the doctoral level. 3 credits, offered every fall term

This course covers *quantitative* methods of inquiry as they are currently used in the study of the contexts, processes, and effects of education. It introduces students to elementary statistics, exploratory data analysis, research design, and computer-based data analysis methods.

- **EDUC 792. Methods in Educational Research: Qualitative**

Prerequisite: Graduate standing at the doctoral level or permission of instructor. 3 credits, offered every fall and winter term

This course covers *qualitative* methods of inquiry as they are currently used in the study of the contexts, processes, and effects of education. It introduces students to elementary statistics, exploratory data analysis, research design, and/or interviewing, narrative and argument analysis, and interaction and setting analysis.

- **EDUC 831. Theory and Research on Learning and Instruction in Science**

Prerequisite: Graduate standing. 3 credits

This course discusses past and current issues in research on learning and instruction in science. It focuses on philosophical issues and theoretical frameworks used to understand how students learn science and examines approaches to empirical work investigating students' learning in classrooms. Students will conduct a small study examining conceptual development that will help them relate the discussions about the applications of research to theory and practice in science education.

Elective Classes (3 credits minimum)

- One class selected in consultation with both the engineering program advisor and the program advisor from the School of Education. Though some courses have prerequisites, it should not be difficult for engineering students to satisfy them through their previous coursework.

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Sample programs for three separate students are included here to demonstrate the feasibility of the certificate. For illustrative purposes, it is assumed that the three students enter the doctoral program in fall 2008. Table 1 illustrates a sample program for a real student who is currently earning a Ph.D. in Computer Engineering and who has a real interest in the program. In this student's department, most students prefer to earn a master's degree along the way. The sample program accounts for that. Following the sample program, this student takes qualifying exams during winter 2010 and takes prelim exams during fall 2012. She will have earned 97 credits when she graduates after five and one half years.

Table 2 shows a sample program of study for a real Ph.D. student in the Industrial Operations Engineering Department who has a real interest in the program. He takes qualifying exams during winter 2009 and takes prelim exams during winter 2010. He will have earned 111 credits when he graduates after five years.

Finally, Table 3 shows a sample program of study for a real Mechanical Engineering Ph.D. student who has a real interest in the program. This student entered the program with a Master's degree. She takes qualifying exams during winter 2009 and takes prelim exams after the winter 2010 term. She will have earned 86 credits (beyond her existing Master's degree) when she graduates after four years.

	Fall 2008	Winter 2009	Fall 2009	Winter 2010	Fall 2010	Winter 2011
	EECS 423	EECS 429	EECS 421	EECS 521	EECS 699	EECS 699
	EECS 420	EECS 520	EECS 523	EDUC 795	EDUC 709	EDUC 865
	EECS 599	EDUC 792	ENG 580	EECS 599	EECS 598	MATH 417
		EECS 599				
Total credits	9	12	9	9	9	9

	Fall 2011	Winter 2012	Fall 2012	Winter 2013	Fall 2013
	EECS 699	EECS 699	EECS 699	EECS 699	EECS 699
Total credits	8	8	8	8	8

Table 1: Sample program for Computer Engineering Ph.D. student

	Fall 2008	Winter 2009	Fall 2009	Winter 2010	Fall 2010
	IOE 510	IOE 518/519	ENG 580	IOE 802	IOE 995
	IOE 474	IOE 543	IOE 512	Math 451	EDU 792
	IOE 562	IOE 545	IOE 549	IOE 541	
	IOE 800	IOE 640	IOE 515	EDUC 795	
		IOE 801			
Total credits	12	15	12	12	11

	Winter 2011	Fall 2011	Winter 2012	Fall 2012	Winter 2013
	IOE 995	IOE 995	IOE 995	IOE 995	IOE 995
	EDU 834	EDUC 713		EDUC 833	
Total credits	11	11	8	11	8

Table 2: Sample program for Ph.D. student in the Industrial Operations and Engineering Department

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	Fall 2008	Winter 2009	Fall 2009	Winter 2010
	ME 505	ME 552	IOE 511	EECS 565
	ME 553	ME 555	ME 990	ME 990
	ME 559	ME 560	EDUC 793	EDUC 792
		ME 990		
Total credits	9	12	12	12

	Fall 2010	Winter 2011	Fall 2011	Winter 2012
	ENGR 580	ME 995	ME 995	ME 995
	ME 995	EDU 626	EDUC 831	
Total credits	11	11	11	8

Table 3: Sample program for Mechanical Engineering Ph.D. student

Faculty Steering Committee

Several faculty in CoE (listed subsequently) have agreed to act as a Faculty Steering Committee, providing limited administrative oversight and acting as mentors and program advisors for the enrolled students. Interested students will be assigned an engineering program advisor who will assist in formalizing professional interests and creating a plan of study that is relevant to the individual's career goals. Throughout the program, the engineering program advisor will be available to provide academic mentoring and career counseling.

Members of the steering committee will also approve variances in the program, review applications and review admission to the program, review the course list annually, and audit students' progress. As the responsibilities are limited, the faculty members have agreed to donate their time, and funding is not required to support faculty.

In addition, Christopher Quintana from the School of Education has agreed to serve on the steering committee. In his role, he will act as program advisor for the School of Education, working closely with students to assist them in planning their program. The full steering committee membership is as follows:

- Cynthia J. Finelli: Director of the Center for Research on Learning and Teaching North and Associate Research Scientist in Engineering Education, College of Engineering
- James Holloway: Arthur F. Thurnau Professor, Professor of Nuclear Engineering and Radiological Sciences, and Associate Dean of Undergraduate Education, College of Engineering
- Susan M. Montgomery: Lecturer IV and Program Advisor, Chemical Engineering, College of Engineering and Instructor for ENG 580: Teaching Engineering
- Kenneth G. Powell: Arthur F. Thurnau Professor, Professor of Aerospace Engineering, and Director of the Center for Advanced Computing, College of Engineering
- Christopher Quintana, Assistant Professor, School of Education and Instructor for several education courses comprising the certificate, including EDUC 601, EDUC 603, and EDUC 626
- Perry Samson: Arthur F. Thurnau Professor, Professor of Atmospheric, Oceanic, and Space Sciences, and Associate Chair of Atmospheric, Oceanic, and Space Sciences, College of Engineering

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Operational arrangements

Administrative support for the program will be provided by CRLT North, and the Director of CRLT North (Cynthia Finelli) will serve as the primary point of contact for the certificate. That office will carry out the day-to day activities for the certificate such as meeting with interested students, receiving and processing applications for the certificate, overseeing admissions and advising, operating general student services, and doing degree audits. The Faculty Steering Committee will oversee these processes and will monitor and assess the program on a bi-annual basis.

To maintain a sense of community among the students pursuing the certificate, CRLT North will provide programs that include the annual Research and Scholarship in Engineering Education Poster Session and relevant workshops on teaching and learning. Students pursuing the certificate will be encouraged to participate and interact in these opportunities.

Enrollment plan

The primary audience for the *Rackham Certificate Program in Engineering Education Research* will be engineering doctoral students who desire an academic career in engineering education or those who wish to pursue scholarship in the new field. Based upon existing interest by CoE graduate students, this number is likely to be small initially, and will be limited to five students per year for the first year. After one year, the steering committee will consult with faculty in the School of Education to reassess the course requirements and enrollment limits.

Any engineering graduate student (in good academic standing) may apply for admission into the certificate program after completing at least one term in a Rackham program. Applications to the program should include four items: (1) a letter of application, (2) a proposed plan of study, (3) a current transcript, and (4) a letter of support from the student's advisor. Applications may be submitted at any time, and they will be reviewed by the Faculty Steering Committee on a rolling basis. Students must maintain cumulative grade point average of B in courses for the certificate program in order to continue in the program, and the requirements must be completed within four years of admission to the certificate program.

Job prospects

The market demand for graduates with training in engineering education is rapidly increasing. The Educational Research and Methods Division of ASEE often advertises positions that would be suitable for students earning this certificate. As a sample of recent openings, six job postings for tenure-track positions and two post-doc postings are attached. Further, graduates with a certificate in engineering education would be a valuable addition to any engineering department.

Financial plan

Since this program is intended to supplement a student's regular engineering doctoral studies, funding is not required to support student research, space, and equipment needs. However, as the program matures, it is likely that more proposals will be submitted to national organizations and those projects may include funding for student research.