Executive Summary

We are proposing the creation of an engineering education research center within the College of Engineering at Montana State University, Bozeman. The center will enable our faculty to better leverage interdisciplinary synergies in order to transform engineering education at MSU and become a leader in an effort of vital national importance. Transformation in engineering education is necessary in order to overcome long-standing issues in undergraduate engineering and computer science programs and educate inclusive communities of engineering students prepared to solve 21st century challenges.

Mission Statement

The mission of the Montana Engineering Education Research Center is to transform engineering education at MSU and become a national leader in engineering education research. This center will enable MSU faculty to tackle the big research questions and challenges facing engineering education today with an overarching vision of improving student success.

Our Goals Are:

- **Significantly increase the research productivity** in the area of engineering education at MSU. Within three years of creating this center we will:
  - Increase the amount of externally-funded engineering education research being conducted at MSU 5-fold from $300k/year to $1.5M/year.
  - Increase the number of scholarly articles published on engineering education by MSU faculty 3-fold from 5/year to 15/year.

- **Initiate large-scale research studies** at MSU to generate empirical findings to address the challenges facing engineering education. Within two years of creating this center we will initiate externally-funded research projects at MSU to further our understanding on how to:
  - Improve student learning of complex engineering concepts.
  - Improve efficiency of engineering education to increase retention and reduce time-to-graduation.
  - Broaden participation of underrepresented groups within engineering, specifically women and Native Americans.
  - Explain why students opt out of engineering during their degree or after entering the workforce.

- **Implement large-scale educational interventions** at MSU to address the challenges facing engineering education. Within three years of creating this center these interventions will create data-driven strategies to enhance student success with specific emphasis on improving student learning, increasing student retention, and broadening participation.

- **Establish MSU as a leader** within the American Society of Engineering Education (ASEE). Within three years of creating this center MSU will increase its national profile in ASEE through holding leadership roles, disseminating our findings in high impact ASEE outlets, and participating in national educational initiatives.

- **Contribute to the training of tomorrow's professoriate** by increasing the number of students pursuing doctoral degrees at MSU through funding by external grants and by providing pedagogical training for Ph.D. students desiring to pursue academic careers.
Strategies

To meet our center’s goals, we will implement the following strategies within the first three years.

- Provide support (course buyouts, summer salary, or stipend) for a center director to coordinate large-scale research efforts at MSU.
- Provide faculty support (course buyouts or summer salary) to meet with program officers, develop proposals, and implement large-scale engineering education research at MSU.
- Provide faculty support (course buyouts or summer salary) to raise our visibility within the American Society of Engineering Education through seeking leadership roles, disseminating MSU’s work through high visibility ASEE outlets, and participating in national educational initiatives.
- Provide support to host a nationally renowned engineering education speaker at MSU each year.
- Provide grant-writing support to faculty developing engineering education proposals.
- Provide administrative assistance on proposal development and project execution.
- Specifically include Ph.D. student support in the educational research grants we propose.
- Develop pedagogical training activities for Ph.D. students at MSU interested in academic careers. We will use courses from the existing College Teaching Certificate (CTC) in addition to mentoring from COE faculty and in-class teaching experience to provide a unique training experience for future professors. This will serve to better train our Ph.D. students wishing to pursue careers in academia, help alleviate the teaching load of lower-level course in COE, and establish MSU as a leader in Ph.D. student training quality.

Motivation for this Center

Educating the engineers of the 21st century has become a national imperative. We need more engineers, more diverse engineers, and engineers who are better prepared to solve complex problems in an interdisciplinary, global context. MSU should be an important player in this national imperative. MSU’s College of Engineering has experienced dramatic growth in the past 5 years. This has led to a record number of students (3000+) and faculty (75).

There are a variety of exciting activities occurring and developing within MSU’s College of Engineering that motivate the creation of this center. First, College of Engineering faculty currently have an unprecedented number of active grants from the National Science Foundation to conduct educational projects. These awards have been won using the traditional lone wolf approach (7 NSF educational grants in the past 5 years totaling $1.3M). We now believe we have formed critical mass in this research area, gained sufficient institutional knowledge on how to propose and conduct this research, and formed critical interdisciplinary collaborations to form a center. Collectively, faculty within the center will be able to win external-funding and output scholarly products at a rate that is higher than individual faculty working alone.
Second, there is a push from the national funding agencies to propose research that is interdisciplinary in nature to solve the most pressing problems of our day. In the field of engineering education research, this means teams must not contain solely engineering faculty, but also researchers from the fields of behavioral & social science and education. A center will provide a formal infrastructure at MSU to facilitate interdisciplinary research on engineering education and lead to an increase in scholarly output by our faculty on critical challenges facing our nation.

Third, there has been a recent increase in federal, foundation, and industrial funding opportunities that aim to advance our understanding of how to better prepare the engineering workforce and promote diversity within the field. Our group feels we are being limited in the number of opportunities we can pursue in our current, lone wolf approach. A center will create synergies that will optimize the proposal preparation process, project implementation, and dissemination and lead to higher research productivity.

Finally, the planned Norm Asbjornson Innovation Center will provide an educational laboratory in which to develop, test, and assess educational interventions and innovations. The creation of this center in conjunction with our new building (whose theme is engineering innovation) will aid us in becoming nationally recognized in the engineering education research arena.

**Seed Funding**

The mission of this center can be obtained with an initial investment in faculty support in addition to grant-writing and administrative assistance. The three year start-up period for the center will focus on initiating large-scale research efforts that can be sustained after the seed funding is expended. The investment will be used for:

- **Annual support for one faculty member to serve as the center director.** The director will be responsible for the overall operation of the center and coordination of large-scale research activities within the center. This support will be used for course buy-outs, summer salary, or as an administrative stipend. Funds will also support travel to other engineering education research centers to heighten the visibility of MSU’s center in addition to learning from our peer institutions.

- **Annual support for three faculty development grants.** These grants can be used for course buy-outs or summer salary support for faculty to develop engineering education research proposals, conduct ongoing education investigations, or develop dissemination products. Funds will also support travel to federal funding agency headquarters to meet with program officers.

- **Annual support for one faculty member to focus on raising MSU’s leadership role in ASEE.** Funds will support activities that raise the profile of MSU within ASEE. Funds will also support travel to ASEE conferences and meetings.

- **Annual support to bring in a nationally renowned engineering education speaker to MSU.** The speaker will give a campus-wide seminar followed by meeting with individual faculty engaged in engineering education research.

- **Non-cash support for grant-writing and administrative assistance associated with center activities.**
Center Contribution to MSU’s Existing Activates

This center compliments and expands upon existing research and development activities on campus.

Potential Return on Investment

Our current *lone wolf* approach toward obtaining external funding has resulted in research expenditures at a rate of $300k per year. Under current conditions, our faculty are able to pursue *small-scale* funding on the order of $75k/each per year (COE currently has 4x of these style of grants). A center will enable our faculty to pursue medium-scale ($150k per year) and large-scale ($600k per year) funding. Under our center proposal, our research capacity will be able to handle two medium-scale and two large-scale projects within three years. This will result in annual expenditures of $1.5M, an increase of 500% over our current lone wolf approach.

<table>
<thead>
<tr>
<th>Annual Expenditures</th>
<th>Annual IDCs Generated</th>
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<tbody>
<tr>
<td>Current Grants (4 small)</td>
<td>$300k</td>
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<tr>
<td>Future Grants (2 medium + 2 large)</td>
<td>$1.5M</td>
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<tr>
<td>(+$1.2M)</td>
<td>(+$528k)</td>
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Faculty Who Will be Active in Center Activities

- Brock LaMeres, Electrical & Computer Engineering
- Paul Gannon, Chemical & Biological Engineering
- Jim Becker, Electrical & Computer Engineering
- Ryan Anderson, Chemical & Biological Engineering
- Carolyn Plumb, College of Engineering
- Colter Ellis, Sociology & Anthropology
- Bryce Hughes, Adult and Higher Education
- Jessi Smith, Psychology
- Nick Lux, Education
- Jennifer Green, Mathematical Sciences – Statistics
- Kevin Amende, Mechanical & Industrial Engineering
- William Schell, Mechanical & Industrial Engineering
- Effat Rady, Head of Pre-Engineering, Flathead Valley Community College, Kalispell, MT
- Kathryn Plymesser, Pre-Engineering, Montana State University – Billings, MT
- Mark Jacobson, Pre-Engineering, Montana State University – Billings, MT
- Thomas Trickle, Professor of Engineering, Salish Kootenai College – Pablo, MT
Faculty Who Have Reviewed This Proposal

Brett Gunnink, Dean, College of Engineering
Anne Camper, Associate Dean, College of Engineering
Christine Foreman, Assistant Dean, College of Engineering
Rob Maher, Head, Department of Electrical & Computer Engineering
John Paxton, Head, Department of Computer Science
Dan Miller, Head, Mechanical & Industrial Engineering
Jerry Stephens, Head, Civil Engineering
Marilyn Lockhart, Director, Center for Faculty Excellence
Jayne Downey, Head, Department of Education
Neil Cornish, co-director, eXtreme Gravity Institute (XGI)

Other Engineering Education Research Centers

- Purdue – School of Engineering Education (ENE)
  https://engineering.purdue.edu/ENE
- Michigan State – Center for Engineering Education Research (CEER)
  http://ceer.eegr.msu.edu/home
- University of Pittsburgh – Engineering Education Research Center (EERC)
  http://www.engineering.pitt.edu/eerc/
- University of Texas at Austin - Engineering Education Research Center (EERC) opens in 2017
  http://www.engr.utexas.edu/eerc
- Northwestern University - NorthWestern Center for Engineering Education Research (NCEER)
  http://www.nceer.northwestern.edu
- Univ. of Michigan – Center for Research on Learning and Teaching in Engineering (M-CRLT-ENGIN)
  http://crlte.engin.umich.edu/
- University of Washington – Center for Engineering Learning & Teaching (CELT)
  http://depts.washington.edu/celtweb/
- MIT – Teaching and Learning Laboratory
  http://tll.mit.edu/help/education-research-mit
- Tufts University – Center for Engineering Education (CEEO)
  http://www.ccee.tufts.edu/research/
- University of Oklahoma – Sooner Engineering Education Center (SEED)
  https://vpr-norman.ou.edu/centers-institutes/list/sooner-engineering-education-center
- University of Illinois – Engineering Education Research Group (EERC)
  https://publish.illinois.edu/engineering-education-research/
Funding Opportunities Available for this Center

- NSF – Directorate for Engineering – Division of Engineering Education & Centers
  - Improving Undergraduate STEM Education (IUSE): Exploration, ($150k over 2 yrs)
  - Improving Undergraduate STEM Education (IUSE): Deployment, ($300k over 3 yrs)
  - Improving Undergraduate STEM Education (IUSE): Transformation, ($3M over 5 yrs)
  - Nanotechnology Undergraduate Education (NUE) in Engineering ($200k over 2 yrs)
  - Research Initiation in Engineering Formation (PFE: RIEF), ($150k over 2 yrs)
  - Research in the Formation of Engineers (RFE), ($300k over 3 yrs)
  - Broadening Participation in Engineering (BPE), ($300k over 3 yrs)
  - Research Experience for Undergraduates (REU), ($330k over 3 yrs)
  - Research Experience for Teachers (RET) in Engineering and Computer Science, ($600k over 3 yrs)
  - Revolutionizing Engineering and Computer Science Departments (RED), ($2M over 5 years)

- NSF – Directorate for Education & Human Resources – Division of Research on Learning (DRL)
  - EHR Fundamental Research in STEM Education: Level 1, ($500k over 3 yrs)
  - EHR Fundamental Research in STEM Education: Level 2, ($1.5M over 3 yrs)
  - EHR Fundamental Research in STEM Education: Level 3, ($2.5M over 5 yrs)
  - Advanced Technological Education (ATE): Planning, ($150k over 2 yrs)
  - Advanced Technological Education (ATE): Exploratory Research & Development, ($300k over 2 yrs)
  - Advanced Technological Education (ATE): Full Scale Research & Development, ($800k over 3 yrs)
  - Advancing Informal STEM Learning (AISL): Planning, ($150k over 1 yr)
  - Advancing Informal STEM Learning (AISL): Exploratory, ($300k over 2 yrs)
  - Advancing Informal STEM Learning (AISL): Practice, ($2M over 5 yrs)
  - Advancing Informal STEM Learning (AISL): Development, ($3M over 5 yrs)
  - Advancing Informal STEM Learning (AISL): Implementation, ($3M over 5 yrs)
  - Discovery Research PreK-12 (DRK-12): Level 1, ($450k over 3 yrs)
  - Discovery Research PreK-12 (DRK-12): Level 2, ($3M over 4 yrs)
  - Discovery Research PreK-12 (DRK-12): Level 2, ($5M over 5 yrs)
  - Innovative Technology Experience for Students and Teachers (ITEST): Strategies, ($1.2M over 3 yrs)
  - Innovative Technology Experience for Students and Teachers (ITEST): Strategies, ($2M over 3 yrs)
  - Innovative Technology Experience for Students and Teachers (ITEST): Center, ($3.5M over 3 yrs)
  - STEM + Computing Partnerships (STEM+C): Exploratory, ($1.25M over 2 yrs)
  - STEM + Computing Partnerships (STEM+C): Development, ($2.5M over 3 yrs)
  - STEM + Computing Partnerships (STEM+C): Broadening Participation, ($600k over 3 yrs)
  - STEM + Computing Partnerships (STEM+C): CS-10k, ($1M over 3 yrs)

- NSF – Directorate for Education & Human Resources – Division of Undergraduate Education (DUE)
  - Scholarships in STEM (S-STEM): Institutional Capacity, ($650k over 5 yrs)
  - Scholarships in STEM (S-STEM): Design & Development, ($1M over 5 yrs)
  - Scholarships in STEM (S-STEM): Multi-Institution, ($2M over 5 yrs)

- Foundations
  - Numerous NGO and NPO Foundations support Engineering Education Research

- Industry (similar to other industry research center funding mechanisms)
  - Industry often invests >$200k to recruit and train new engineers. Many companies hire >10 MSU engineering graduates annually. MSU currently graduates >500 engineers annually. There is significant potential for industry funding to improve quality of engineering education and recruitment of graduates.
Survey Feedback on the Center from COE Faculty

A survey was sent out to all faculty and staff within the College of Engineering in February of 2016 to gauge interest in creating an engineering education research center. There were 141 people invited to complete the survey. There were 66 responses (47% response rate). The survey consisted of five questions. The following plots show the results of the survey and the verbatim comments.
Do you have any additional comments about engineering education research? (Optional)

- We still need more people to teach basic engineering courses - without the basics the students lose.
- There should be some level of interaction with local companies. Get them involved.
- This seems like the perfect time to establish an engineering education research center.
- I have done both engineering education "research" and more traditional product/materials/investigative research: From those efforts and the work of others I've determined that engineering education research is a soft side effort, aligned only loosely with effective teaching. I think most engineering education research is performed to generate papers/presentations at conferences attended by others who have done similar work, but dissemination of this work to a larger audience is weak. Adoption of 'novel' approaches is also weak. I think this type of work does help a little to further engineering education but only just. It is not well aligned with more traditional research efforts which are more valuable across the board.
- COE should seek external support for this as well.
- As far as the research center goes, it would depend on what the goals and plan of execution was.
- I do believe engineering education is a valid research endeavor as even a mutual component of more traditional research, however, I am not sure I feel it would be valid as an engineering faculty's only research endeavor.
- I believe that engineering education research is increasingly skewed towards the trendy - so called innovations (which usually aren't), and diversity - while marginalizing the realm of actual engineering learning. If the MSU COE invests in this, it would be nice to have some assurance that the resources won't be siphoned off into the wasteland of the trends of the day.
- While certainly a good idea, we have plenty of good ideas in the COE. If like-minded faculty want to coalesce and join together, then go ahead! However, if this was science based research, COE resources wouldn't be requested.
- It is about time!
- I am a research professor and do not teach.
- Having resources (training, examples, support, etc.) available would significantly increase/improve the chance of including research into the classroom.
- COE funding should be used for more pressing needs related to facing the growing enrollment. Examples are TAs support, scholarships, possibility to have several section of a single course in order to decrease to number of students per class.
- Discussions/presentations on the topic at MSU would be useful.
- It helps busy professor do their jobs more effectively and is incredibly valuable. Its nice to have someone distill the current research into a ready to deploy classroom technique.