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Strategic Planning Summer Working Group Report
BS Degree 2.0: The Evolution of the Former BS in Engineering Degree
August 10, 2015

Section 1: Charge

Proactively consider either sunsetting the old B.S. Engineering degree[1] or reformulating this degree in a way that adds value to the institution.

Section 2: Relationship to Strategic Plan

This committee's efforts help advance the following goals of the strategic plan:

Goal 1: Enhance the distinctive identity and reputation of Mines

- 1c Expand active-learning instruction (such as studio and project-based, rather than traditional lecture format) utilizing best-in-class pedagogical and technological practices
- 1d Improve and expand opportunities for participation in professional practice and research throughout the entire undergraduate experience
- 1e Expand and enhance graduate student development of professional attributes through formalized activities and curricular excellence

Goal 2: Build upon a student-centered campus culture of excellence, inclusion, diversity and community.

- 2a Expand residential campus to integrate efforts from academic affairs and student life, for undergraduate and graduate students, to promote student community and to foster collaboration, learning, leadership and citizenship
- 2b Advance academic culture and structure that fosters creativity, intellectual-curiosity, and student success
- 2c Enhance opportunities for students to develop effective communication skills as a complement to strong content expertise
- 2d Build a campus that values employees and students of the institution through a positive, supportive, and inclusive environment
- 2e Increase the diversity and quality of Mines' faculty, student and staff

Section 3: Membership

Working Group members: Kevin Moore, Chair; Peter Han; Nigel Middleton; Jeff Holley; Mark Mondry; Graham Mustoe; and John Persichetti. Individuals also participating: Jered Dean, Juan Lucena, Linda Layne, Katie Johnson, Alexandra Newman, Cameron Turner, Leslie Light

[1] The CSM 2014-2015 undergraduate Bulletin references the B.S. Engineering degree (with specialty) as suspended after the fall of 2013. The applicable section of the Bulletin is available online at: http://bulletin.mines.edu/undergraduate/undergraduateinformation/undergraduatedegreerequirements/

Section 4: Summary of Deliberations

The committee has had two extensive face-to-face meetings, though various subsets of campus have been discussing this topic since April 2013 in response to our most recent ABET visit[2].

In brief, given the newly-accredited BSCE, BSEE, BSEnvE, and BSME degrees, the former BSE with Specialty degree is redundant. The former BSE is still "on-the –books," but admissions to the degree program are currently suspended. A need exists to either eliminate or revise the degree.

Emerging trends in engineering education suggest that there can be merit in retaining a revised "general engineering" type degree. Early discussions identified two ends of the spectrum: revise the BSE to be either

- "Designer degree": Take core coursework, build a 12-18 credit "secondary area" – all entirely from existing Mines classes; minimal effort/minimal distinction.

- "Innovative degree": Take core coursework, build a 12-18 credits "secondary area" – but, add new integrated design/innovation, project-based, best practices experiences in each year or semester; more effort/more distinction.

Committee consensus, based on a number of factors (see Section 7), was that the "minimal effort designer degree" would be neither distinctive nor desirable.

This consensus then led to discussion about what an "Innovative BSE" would look like (called the BSE 2.0 in the remainder of this document). To address this, the committee considered an approach to define Mission/Vision/Program Educational Objectives (PEOs)/Student Outcomes (SOs), following common ABET parlance. A summary of our current thinking on these topics follows, as well as a summary of other key considerations:

1. Possible BSE 2.0 Mission Statement

The BSE 2.0 should reflect a paradigm shift in engineering education for the future, from the traditional discipline-centric course of study to a broad-scope, application-driven approach encompassing a multi-disciplinary science and engineering pillar coupled with social/cultural and environmental pillars. Inherent in the BSE 2.0 should be the mindset of human-centered design and all this entails, including application areas in the curriculum that place emphasis on business and entrepreneurship, intellectual property development, economics, business development, and project management, as well as sustainability, cultural, and community integration as those topics intersect engineering.

[2] Constituent Advisory Board (CAB) meeting April 2013 as an ABET-related activity; BSE "Committee" (Bach, Mooney, Turner, Johnson, Moore, Steele, Zhang) met approximately monthly from 2012-2013); Early Feb 2015 scoping effort by Moore, Dean, Johnson, Light, Lucena; meeting with Moore, Han, and Middleton, Spring 2015; meeting with Moore, Walls (EB), Gianquitto (LAIS), Spring 2015; recent email discussion/ assignments to current committee members; employer interest survey in Spring 2015.

Mission: The BSE 2.0 program educates the next generation of engineering innovators, design thinkers, and impact makers who will be leaders in defining and solving problems in socially responsible ways, to advance an ideal of attaining a sustainable global society.

Characteristics of BSE 2.0 include:

- The degree emphasizes curricular breadth, as distinct from the disciplinary depth that characterizes the family of Mines' other engineering degrees.

- The degree will achieve intellectual credibility in engineering circles by orienting the studies around selected technical applications of major societal importance, as represented, for example, by the NAE's list of Engineering Grand Challenges and major thematic areas embedded in Mines mission[3].

- Relevant business and social drivers in the application areas will have prominence in the curriculum.

- The degree will be a platform for employment in sectors aligned with the application areas, or for graduate studies in an engineering discipline, or for studies leading to a professional degree.

Note that while we do not believe that all engineers should be educated outside a disciplinary focus such as the proposed BSE 2.0[4], we believe that some should and that Mines should have such an option available in their degree offerings.

2. Possible Program Educational Objectives

Within several years after graduation, graduates of the degree will be engaged in progressively more responsible positions as:

Innovators: BSE 2.0 graduates are innovators who are comfortable taking risks and who are energized by the belief that engineers help to make the world a better place while improving people's lives.

Design Thinkers: BSE 2.0 graduates are confident in their abilities to approach engineering problems from a human perspective and to identify alternative design solutions before converging on an optimized end result that balances technical, economic, environmental and societal goals.

Impact Makers: BSE 2.0 graduates are much more than engineers, with a broad perspective to see new opportunities and to make a positive impact on people, organizations, the environment, and society.

[3] Topics suggested by the Committee: public infrastructure; energy security; water security; utilization and management of natural resources; waste management; and engineering aspects of public health. Note that the initial set of application/focus areas are expected to align with existing Mines expertise and the "Earth, Energy, Environment" narrative, but we expect it is possible that new application areas can emerge based on Mines' strategic plans, faculty and student interests, and society's needs.

[4] However, it is clear from the trends in pedagogy related to engineering education, that all engineers should be exposed to many of the concepts that would be inherent in the BSE 2.0.

3. Possible Student Educational Outcomes

Upon graduation from the BSE 2.0 program, students will be able to:

- Exhibit a high level of creativity and advanced problem solving skills – drawing upon broad understanding of technical/social/political/environmental/economic dimensions inherent in complex, multi-faceted project developments.

- Confidently work in and lead multidisciplinary teams, recognizing and mobilizing the different skillsets necessary to achieve a particular design, and marshalling diverse expertise and stakeholder interests to achieve a common project goal.

- Recognize and integrate cultural, social, political, economic and environmental resource constraints into the establishment and execution of an engineering project.

- Demonstrate exceptional communication skills (listening, writing, speaking, persuading), and be adaptive to technical and stakeholder audiences, including being empathetic to other cultures, perspectives, and motivations, while recognizing the limitations of engineering approaches.

- Improve the global quality of life through an understanding of influential factors in design, and demonstrate a comprehensive viewpoint throughout the process while giving proper deference to a community's desired cultural and social identity.

- Drive smart public and corporate policy development.

- Achieve innovative, sustainable business and community development practice.

- Apply academic learning to real-world engineering projects in a manner that is similar to how leading multinational companies approach real world opportunities;

- Use "business sense" to see engineering problems in a larger commercial and societal context, and confidently use their abilities to pursue entrepreneurial and Intrapreneurial opportunities during and after their undergraduate studies at Mines.

- Demonstrate core knowledge and skills per ABET accreditation criteria (ABET Student Outcomes (a)-(k) met by this program).

4. Possible Program Elements

The BSE 2.0 would deliberately foster:

- Technical Competence - Each student completes an approved course of study in one of several to-be-determined "areas of specialization" or focus areas (note: ABET considerations arise here).

- Collaborative Competence - Each student develops extensive collaborative skills in the areas of: (1) working in cross-disciplinary teams; (2) project management; (3) communications (listening, written, and verbal), and, developing (1)-(3) with the goal of (4) defining and solving problems within the constraints of diverse perspectives, both technical and social.

- Leadership Competence – Each student demonstrates leadership acumen by performing a leadership role in a combined technical/socially-drive project.

- Entrepreneurial Competence – Each student completes an entrepreneurial activity as a component of the undergraduate course of study (innovation competition, startup creation, e-team, or other approved activity) and is able to demonstrate strong business aptitude to see engineering problems in a larger commercial and societal context.

- Sustainable Society Competence – Each student demonstrates competence in addressing the social and environmental realities of their work in an area of overlap with one or more of their chosen areas of specialization or focus.

Program elements are envisioned to include:

- Hands-on experience with several real world design projects categorized into Application Areas, demonstrating both technical and socio-economic contribution to the project objectives (application areas based in science and engineering design where "smart designs" have a significant regional or even global impact – see Footnote 3 above).

- Extensive exposure to multi-disciplinary engineering design understanding, integration and execution in course and client work (the BSE 2.0 degree program will strive to have 3 or more traditional discipline-centric engineering programs involved in each application area project, and students versed in all facets of the technical design) – strong technical knowledge in engineering, but with more breadth than depth.

- Each student serves as Project Manager on one or more multi-disciplinary student design projects.

5. Potential Student Base for Degree

The BSE 2.0 would attract ambitious students with a passion to make a positive impact to our daily lives by leveraging their aptitudes in science and technology to address societal and environmental needs on a local, national, and international scale. The degree would cultivate engineers who want to utilize a multidisciplinary, broad-based core of skills to rebuild, recreate, and bring to life unimagined approaches to the future of the world.

We envision the program will attract an interesting collection of engineering students with a desire to have significant influence over multiple facets of a project together with those students who simply do not want to be limited by a specialized degree and who value a broad-based knowledge foundation – engineers that look beyond mastering their discipline to focus on the fruitful outcomes culminating from the development of their core knowledge. We envision the population making up the student body for the BSE 2.0 being as diverse and rich as the offering itself. Among many potential sources the degree will draw principally from three groups:

- Typical CSM applicants whose aptitudes and interests transcend a specialty.

- Students who otherwise would not consider CSM and who seeks the strength of a diverse and application-oriented program that is differentiated from traditional discipline specific engineering degrees.

- Students desiring a thoughtful, thorough exposure to engineering as a foundation to launch an academic career that includes graduate degrees in law, medicine, or business in pursuit of professional opportunities beyond engineering.

6. Potential Employer Base for the degree

Graduates of the BSE 2.0 program will be well-positioned to work in leadership roles in a wide range of industrial, governmental, academic and non-engineering related disciplines. Some examples are described below:

- Organizations operating in new, fast-changing and dynamic technology- and product-based industries that are seeking technically-innovative and socially-responsible employees that can work effectively in continually changing working environments that produce new technologies and products. Examples of such companies are Google, Amazon, Apple, 3M and Tesla.

- Government agencies and entities that need policy advisors with a broad science/engineering background combined with expertise in areas such as sustainability and resource management and have strong communication skills. Examples of such agencies and entities include the White House, US Senate and Congress, and various US federal and state government agencies, such as CDC, EPA, FDA, DOE, DOI, NIH, etc.

- Engineering consulting and design companies focused on projects related to energy issues, sustainability and the environment who need employees that are technically and analytically competent yet socially aware in design concepts and able to connect and integrate perspectives and realities that are outside of the typical engineering perspective. Examples of such companies are URS Corp, CH2M Hill, Jacobs Engineering, and Wright Water Engineers.

- Financial firms, law firms, health care providers who need high-level financial, legal and medical professional employees with a strong science and engineering background. Examples of such companies are J.P. Morgan and Chase, Kaiser Healthcare, and Kilpatrick Townsend (Denver High-tech IP Law firm).

- Technology-based companies looking for employees who are equipped to excel in today's project based, self-organizing and agile working environments (i.e., they are self-directed and creative).

- Organizations looking for technical leaders who embrace risk as a necessary avenue to growth and innovation.

- Organizations seeking employees who are technically and analytically competent, yet able to connect and integrate perspectives and realities that are outside of the typical engineering perspective.

- Consulting firms, financial firms, law firms, health care providers (i.e., BSE 2.0 graduates are the type of individuals who will go on to graduate and professional degree programs outside of engineering).

- Graduates should also be well-suited to become self-employed entrepreneurs who can create and build companies whose businesses are focused on the development of innovative products, designs and technologies in a socially responsible manner.

- Graduates will be prepared to enter graduate school to obtain graduate degrees in engineering or professional degrees in non-engineering related areas such as medicine, law or business.

7. Other Comments

We envision studies in the new BSE 2.0 degree to be organized around two axes: one targeted toward specific world-wide challenges and the other targeted toward technical areas associated with potential innovative solutions.

Potential broad challenge areas where the BSE 2.0 students might engage include[5]:

- Energy (Energy Development, Sustainable Energy)

- Water Security (Water quality, supply storage and management, effective usage domestic and industrial/commercial usages)

- Natural Resource Management and Utilization (Mining and Fossil Fuel Extraction, Water usage, Agricultural Resource Management and Effective Utilization)

- Waste Management (Collection, Transport, Treatment/Re-cycling, Disposal, Control, and Minimized Production / Prevention)

- Infrastructure Development (Urban design, Cities of the future, Maintenance, improvement and renewal of current aging infrastructures)

Possible technical focus areas in the new BSE 2.0 degree might include:

- Business, Politics and Economics

- Engineering Design Optimization

- Sustainable Design

- Smart Materials

- Innovation and Entrepreneurship

[5] As noted in a previous footnote, it is expected that initial areas are consistent with existing capabilities and focus at Mines, but as the program develops, one could consider expansion to new areas, for example, perhaps in the important area of International Public Health and Safety (Disease Detection, Isolation and Mitigation, Legal Regulations and Political Constraints).

- Environmental Science
- Sustainable Energy
- Humanitarian engineering and corporate social responsibility

Note a student could also design customized challenge and technical focus areas with guidance and formal acceptance from a faculty committee within the BSE program.

Section 5: Recommendations/Observations

The deliberations reflected in Section 4 resulted in a striking, but aligned, consensus in our working group: our ambitions are big. The BSE 2.0 design process will involve the creation of new courses, amplification of cross-disciplinary teaching, and creative pedagogy that stimulates the explorative intellectual curiosity within the minds of the target students we aspire to graduate from the program.

For example, there are numerous avenues for achieving the envisioned student competencies outlined in Section 4.4 above. Most, if not all, of those competencies include an elevated level of practical student project opportunities that provide students with learning experiences through team-based collaborative doing. Not just learning what should be done, but actually doing it - learning by doing[6]. These learning experiences could include things like co-curricular innovation competitions, enhanced student entrepreneurial resources, access to "maker spaces" and support for new relevant student clubs, organizations and co-op/internship opportunities. There are opportunities to intersect the BSE 2.0 with the NAE Engineering Grand Challenges. There are further opportunities to integrate more business acumen and societal/environmental empathy into the BSE 2.0 program courses and activities. These efforts will require a deliberate focus of resources.

Of course, many of the existing engineering degree programs at Mines would also benefit from the activities and resources we envision critical to the success of the BSE 2.0 program. Thus, the working group sees a compounding benefit to the entire institution as a result of successful implementation of the BSE 2.0 vision. Ideally, many of the student outcomes envisioned for BSE 2.0 could be applied to discipline specific engineering degree programs at Mines and new courses and resources would be shared. Clearly, the engineering education landscape is changing – the working group sees the development of BSE 2.0 as a unique opportunity to design and apply some of these initiatives at Mines in an accelerated manner.

Our ambitions for BSE 2.0 are most likely achieved in deliberate steps. These steps are outlined below.

Section 6: Next Steps

We plan the following activities during the fall semester, leading up to a final report:

- Incorporate any potential findings, as appropriate, from the McBride Honors retreat discussion on the role of honors programs on campus.
- Incorporate the results of discussions during the fall 2015 Faculty Conference.

[6] "Engineering by Doing," as Dean Moore likes to call it.

- Integrate findings and recommendations from other working groups, in particular the 1st and 2nd Year Experience group, and Programs of Distinction group.

- Conduct a brief, informal market assessment of the proposed degree working with admissions and the career center, expanding on the Employer Survey completed in May 2015[7] and potentially including an informal survey of 1st year students using an appropriate core course as the audience.

- Identify department champions for the degree.

- Determine any applicable ABET timeline, if desired.

- Outline a proposed BSE 2.0 curriculum.

- Identify co-curricular resources needed and timeline for implementation.

- Establish proposed budget.

- Prepare BSE 2.0 Final Report to present to Academic Affairs.

Section 7: Resources/References Consulted

- Websites for general engineering programs at a number of schools, including Olin College of Engineering, Harvey Mudd, CU Boulder, Stanford, ASU, Illinois, RPI, Lehigh, and Carnegie Mellon, among others.

- Web searches and interviews with colleagues at other institutions to see how "general engineering" is perceived from the academic, industrial, government and social perspectives – are "we" all on the same general page when it comes to the meaning of general engineering? For example, we found that some institutions insert a general engineering degree into an honors program to elevate the degree and avoid the potential for prospective students to view the degree as "inferior" to a discipline specific degree.

- Reviews of some committee member's personal resources in engineering management training: Honeywell 6-sigma training, UC Irvine Management Certificate Program (in technology-based businesses), and reflection on social and cultural aspects of past consulting projects and what would help in a degree program to prepare students for work on these sorts of future projects.

- The recent book titled *The Whole New Engineer*, (authored by David Goldberg and Mark Summerville, published in October 2014) describing innovations in engineering education at Olin College and the University of Illinois.

- CSM Employer Interest Survey.

[7] In this preliminary survey 50.91% of 110 companies responding indicated that they would be interested in graduates from the BSE 2.0 concept.