



Baccalaureate Program of Sustainable System Engineering – Objectives and Curriculum Development

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Abstract

While post-graduate sustainable programs have been very well developed in universities, until recently, baccalaureate education in sustainability has been largely underrepresented. With the success of the post-graduate programs in a wide range of individual sustainable development areas, such as environmental sustainability, sustainable manufacturing, infrastructure sustainability, etc. the time seems appropriate for creating a baccalaureate program in Sustainable Systems Engineering (SSE) which can form a pipeline of students educated from a systems perspective in sustainable engineering practices that will feed into post graduate programs, as well as fill a need in government and industry. The baccalaureate SSE will focus on more general and multidisciplinary areas of sustainable engineering systems to prepare students for future sustainable development challenges. This paper studies three major aspects of the development of the baccalaureate SSE program at the Metropolitan State University of Denver: (a) Necessity of SSE, (b) Objectives and (c) Curriculum Development.

Necessity of the development of sustainable system engineering baccalaureate program

Sustainable development requires engineering engagement in the assessment and identification of potential issues. The development and improvement of science and technology has deeply influenced our daily lives. While the technology has led to a better, easier and more comfortable life for people, it also has had a profound impact on the global environment. Sustainable development necessitates a systemic methodology which utilizes fundamental engineering skills coupled with a holistic problem solving approach. Sustainable development requires identification, assessment and analysis of the issues for a potential development project. The lack of information and knowledge of our impact on the environment has been widely recognized. In example, the National Science Foundation has successfully sponsored the National Ecological Observatory Network (NEON) for examining continental-scale ecological change over time. This network provides planners with ecological data to help identify potential problems caused by development. Additionally, many government agencies have installed high-tech surveillance and monitoring systems for traffic control, natural disaster monitoring, and assets management. The private sector also contributes to identify sustainable development issues. IBM has established a Smarter Cities Challenge Fund to help 115 cities in last four years to address the key challenges facing urban cities around the world. In these examples engineering is playing a critical role in developing and understanding of the environment. However, the engagement of the data collection, integration and analysis and other engineering tools lags behind the current research. Effective implementation of the information and data in sustainable development projects requires engineers to have a broad spectrum knowledge of civil, electrical, mechanical, and environmental and energy areas. The current engineering education system has been successfully training qualified engineers in specific fields. The quality of the U.S. engineering

education has been widely recognized globally. The advances in science and technology and the creative works by US engineering schools make the nation a leader in innovative technology development in the world. In contrast, the lack of an integrative systemic engineering knowledge limits the vision of US engineers in the leadership of sustainable development.

Sustainable development requires engineering engagement in policy making, risk analysis, and disaster management. Engineers have developed technical specifications, standards, guidelines, regulations and building codes in many areas. However, it is realized that engineers should also play an important role in policymaking, legislative and other administrative activities. In recent years, the US government has reached out to strengthen relationship with professional organizations, such as ASCE, ASME, IEE and ASEE. The solutions of sustainable development are no longer an individual technical or social problem. They require a full commitment and corporations from all social parties. The SSE program should provide students with a better understanding of the fundamental social knowledge in political system, governmental operations, regional economic development, natural resources, urbanization, globalization, public health etc. The SSE program will aim to create a bridge that closes the gap between engineers, politicians and sociologist. SSE students will be trained to view a developing project from a social structure or systemic prospective instead of a problem of individual disconnected parts. Engagement of engineering in government operations will not only integrate all resources for scientific decisions and ensure sustainable economic development, but also minimize the possible impact of natural disaster and other unfortunate events.

In addition, sustainable development requires engineering involvement of public relationship and public affairs with knowledge of behavior science to solve problems. NIBY (Not-In-My-Back-Yard) problem is one of example of misunderstanding the relationship of sustainable development and environment protection. While people enjoys the great achievement of technology, they also oppose proposals of new development of infrastructures, industry parks, military bases, commercial and entertainment centers, landfill and waste materials process plants, and even some humanitarian facilities near their communities. NIBY problem is beyond the solution of engineering scope alone. It consists of complex approaches of technology, environment management, public health, and an understanding of human behavior and social and cultural traditions. Engineers have to establish a strong partnership and maintain a decent communication with the public, local communities, government and developers. It is the responsibility of engineers to train and educate the public to understand that the sustainable development must not compete with natural systems. Instead, the problems must recognize that nature is a partner and work with it to achieve a better, more sustainable solution. To work within this paradigm, the SSE program will provide engineering students with a solid knowledge of public affairs and communication skills.

Finally, a successful sustainable system baccalaureate program can form a pipeline of students educated from a systems perspective in sustainable engineering practices that will feed into the post graduate programs, as well as fill a need in government and industry. The bachelor's degree of sustainable development has become popular in last decade. Master's degrees, Ph.D. degrees and non-credit certificates programs are also offered in many universities in the U.S. and around the world. Since the topics of sustainable development cover a broad spectrum area, the

programs in different universities place emphasis on different fields such as sustainable economy, sustainable energy, sustainable agriculture, sustainable structure, etc.

Graduates of SSE will be able to join the workforce as engineers. A sustainable systems engineer is expected to work on or lead projects requiring a systemic and interdisciplinary approach to prevent the mismatch between a sophistication of individual discipline decisions and complex situations that benefit long term sustainable development

Objective of sustainable system engineering baccalaureate program

The SSE program comes from a need to develop a sustainable vision and leadership model for engineering students which prepares those students with a curriculum that encompasses a regional and global perspective of sustainable development theory, relying on a sound understanding and application of engineering fundamentals and coupled with an emphasis on communication skills. The objective of the SSE program is integrating sustainable and systems engineering to provide students with more comprehensive prospective view of human well-being and development. It emphasizes on two aspects: 1) the vision of sustainable development and 2) the leadership of sustainable development.

Future engineers should be able to see a systemic picture of a proposed project. They should be able to understand the impacts of the prospective project on the environment, the economy, society and human well-being in both the short term and long term. To achieve the objective, the SSE program should provide students with a fundamental knowledge of civil, electrical, mechanical, environmental engineering and social science, such as economics and political science. The leadership of engineers requires students to establish the competence of responsibility, integrity, ethics, proactivity and communication skills.

Systems engineering is a shifted paradigm from traditional engineering approaches. This method focuses on engineering solutions from a broader perspective that includes optimization parameters, long term lifecycle analysis and advanced methods to characterize and solve complex problems. Sustainability is an important aspect to consider in the methodology of today's engineering challenges and there is a very real demand in industry for graduates who have had training in sustainability and understand the systems approach

Upon finished the program, the students should be able to:

- Apply the knowledge and methods of the social and natural sciences to understand and analyze engineering problems and to provide solutions
- Develop interdisciplinary critical thinking, communication and problem solving skills for sustainable development projects
- Build leadership in planning, building and implementation of sustainable development

Curriculum Development sustainable system engineering baccalaureate program

The curriculum for the SSE program is modeled from the guidelines of ABETS requirements for Systems Engineering. This necessitates that the education provides students with the knowledge of fundamental engineering practices, such as environmental, infrastructural, manufacture

engineering and natural resources; the knowledge of political/social systems such as communication, public/governmental relationship, behavior science and globalization and the knowledge of fundamental economy and business practices such as regional and global economy, marketing, information system.

The Sustainable Systems Engineering Program will emphasis on the interactions of society, engineering and ecological systems. Specifically, the program studies the relationship of engineering to economic development, environmental impact, social structure, and the sustainability of natural resources. The program will examine how social, political, and engineering activities influence human well-being as a whole complex system and will provide students with knowledge and methods to analyze and solve sustainable development problems. The program description of the Sustainable Systems Engineering (SSE) will be: apply a holistic and systemic approach to solving problems and move beyond the tradition of breaking designs down into disconnected parts

Accreditation Board for Engineering and Technology (ABET) has not specified the criterion for Sustainable System Engineering yet. The curriculum development of the SSE program is based on the criteria for Engineering, General Engineering, Engineering Physics, Engineering Science, and Similarly Named Engineering Programs and for Systems and Similarly Named Engineering Programs. The ABET general requirements are:

- a. One year of a combination of college level mathematics and basic sciences (some with experimental experience) appropriate to the discipline. Basic sciences are defined as biological, chemical, and physical sciences
- b. One and one-half years of engineering topics, consisting of engineering sciences and engineering design appropriate to the student's field of study
- c. A general education component that complements the technical content of the curriculum and is consistent with the program and institution objectives

Since the curriculum of the SSE program is still under development, this paper focuses on 1) how the curriculum aligns with the program educational objectives, 2) how the curriculum and its associated prerequisite structure support the attainment of the student outcomes and 3) how the SSE program meets the requirements in terms of hours and depth of study for each subject area.

SSE program is a diversified interdisciplinary program. It integrates the fundamental educational objectives of Science, Engineering, Business, Political Studies and Communication. The diversified academic programs, student bodies and the integrated Engineering Technology of Civil, Electrical and Mechanical Programs at Metropolitan State University of Denver gives the university an exceptional advantage to develop a new bachelor's degree of Sustainable Systems Engineering program. This program will incorporate current interdisciplinary majors of social sciences, natural science and engineering across the campus to provide students with the knowledge, skills, and leadership needed to ensure high professional standards and protect public safety, health, welfare and through sustainable development practice. The curriculum will be continually updated to reflect the growth of the development of human society with regard to sustainability and to meet the needs of industry and the community. In addition, an industrial advisory board (IAB) consisting of employers, graduates, and current students of the program

will be formed and meet with the faculty and administrators regularly. The IAB will review curriculum, students and faculty requirements, program needs, facilities, and to assist in the placement of interns and graduates. The intention is to ensure a high level of community awareness and support of the program and input for continuous improvement

To associate prerequisite structure support the attainment of the student outcomes, a minimum grade of “C” is required for all prerequisites before a student can progress. A full-time student may complete the program in four years (eight semesters). All students completing SSE program must participate in the Fundamental Engineering (FE) exam during their senior year. The SSE has more rigorous mathematics and physics requirements, which is definitely different from the individualized degree, i.e. the engineering perspective requiring more analytics and a more technical approach. The general study session of the SSE program fits well with pre-engineering transfer standards for community college students with a few additional required courses specifically for SSE degree, such as Political Systems and Ideas, Globalization – The Transformation of Social Worlds, etc. The general study courses will lay the foundation for the students to gain better understanding of the political and social world as they lead and/or participate engineering design and development.

To meet the requirements in terms of hours and depth of study, The SSE program will offer both day and evening classes to meet the needs of the diverse student population at Metropolitan State University of Denver. The SSE program students are required to take totally 127 credit hours for graduation. The program consists of:

- General Study (55 hours), which includes written and oral communication (9 hours), history (3 hours), political science, globalization and ethics (9 hours), art and humanities (3 hours), quantitative and analysis (31 hours)
- SSE core courses (66 hours), which includes fundamental courses of civil, electrical and mechanical engineering, such as Fluid Mechanics, Thermodynamics, Engineering Mechanics, Engineering Graphics, Material Science, Structural Engineering, Geotechnical Engineering, Machine Design, Process Control System, Basic Electronic Systems, Advanced Energy, and fundamental general engineering course, such as Technical programming, Stochastics, Engineering Safety, Behavioral Science in Engineering Practice, Engineering Economy, Development Economics, etc.
- Upper division elective (3 hours)
- Capstone and thesis (3 hours)

In addition, the following core sustainable courses for the SSE major are developed:

- Introduction to Sustainable Systems Engineering;
- Sustainable Development Strategy;
- Life-Cycle Analysis and Systems Engineering
- Capstone: Thesis in Sustainable Development.

In conclusion, Sustainable Systems Engineering is a broad discipline that addresses the engineering of large, complex systems and the integration of the many subsystems that comprise the larger system. The SSE program under development at the Metropolitan State University of Denver needs a multidisciplinary collaboration, not only within the area of engineering and technology, but through other social and environmental sciences as well. To this direction, the required courses will also include environmental science, political science, economics, and much

higher level of mathematics than the current technology programs that the department offers. The SSE program will prepare students to meet the increasing demands of the job market in planning, managing and operating sustainable engineering systems and it will benefit the graduates who might find employment in areas such as city engineering, government engineering administration, engineering company marketing persons and controllers, systems engineering, environmental engineering and development work.

References:

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