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Educational Innovation in a new Online Sustainable Systems Engineering Masters Degree Program through Cross-Campus Collaboration

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Carl Vieth is the Director of Corporate Education for the Department of Engineering Professional Development at the University of Wisconsin – Madison. In this role, Carl brings the tremendous resources of the University to the engineering and technology community in business and government. Carl has been instrumental in forging College of Engineering corporate partnerships, and creating the Competency Modeling program within the Department of Engineering Professional Development (EPD). In addition to his appointment in EPD, Carl is a frequent lecturer for the University's Center for Advanced Studies in Business and leads process improvement projects across campus.

Prior to coming to the University, Carl was a Senior Consultant with GE Healthcare specializing in Cardiology, Emergency Services, Clinical Information Systems and Healthcare Administration. GE Healthcare is a global provider of healthcare technologies and services. Carl came to GE with the acquisition of Marquette Medical Systems, where he was the Director of Corporate Education. In this role, Carl had global responsibility for sales, technical, and customer training programs. As a Six-Sigma Black Belt, Carl led internal and customer-based performance improvement projects ranging from sales and commercial operations to clinical delivery systems and financial performance.

Carl's teaching interests and experience reflect a wide range of development activities. Carl leads lean-six sigma training and development as part of the administrative process redesign initiative and the administrative excellence strategic initiative at the University of Wisconsin. In addition, Carl is a frequent lecturer on patient safety and healthcare system optimization. As the co-director of the technical leadership certificate program, Carl was instrumental in forging beneficial teaching partnerships with the Wisconsin School of Business.

Prior to coming to the UW, Carl managed global corporate training and development at Marquette Medical Systems, and continued in that role following the acquisition of Marquette by GE Healthcare. In that role, Carl was responsible professional sales training, leadership development programs, and related continuing education programs for 3,000 globally distributed employees. In this role Carl also designed, developed and administered customer clinical training on a wide range of critical care and cardiology clinical systems.

Carl has held senior leadership positions in various healthcare organizations in Southeastern Wisconsin. Within his experience as a healthcare administrator, Carl has directed a Cardiology Center of Excellence, lead an enterprise-wide marketing effort, and performed operations management as an Assistant Director of Nursing for Critical Care.

Carl earned his Diploma in Nursing (Honors) from St. Luke's Hospital School of Nursing and his Bachelors of Science in Nursing (Cum Laude) from Milton College. He received his Masters Degree in Curriculum and Instruction from the University of Wisconsin-Madison. And has completed coursework towards his PhD in Cultural Foundations in Education from the University of Wisconsin-Milwaukee. He holds a Certificate in Sales Management from the University of Wisconsin Center for Advanced Studies in Business, and Six Sigma Black Belt Certification through General Electric Corporation.

Prof. Patrick Eagan, University of Wisconsin-Madison

Patrick Eagan is a professor at the University of Wisconsin-Madison, Department of Engineering Professional Development and is co-appointed in the Civil and Environmental Engineering and the Gaylord Nelson Institute for Environmental Studies through which he develops and offers continuing environmental engineering education to practicing professionals. He currently chairs the Environment and Resources program in the Gaylord Nelson Institute for Environmental Studies and is a Sustainability Fellow in the Campus Office of Sustainability. He is currently in charge of developing campus sustainability metrics. Dr. Eagan has been actively involved internationally in the development of design-for-the-environment tools and education since 1992. He has worked with many companies tailoring educational programs on the emerging topics of environmental awareness, life-cycle management/design-for-the-environment, environmental management systems, and environmental purchasing. In addition to his research in industrial ecology, his outreach courses include a range of topics including wastewater treatment and collection, stormwater quality and restoration of water resources. At the University of Wisconsin-Madison, he teaches sustainability competencies and industrial ecology for engineers on line as a part of the Sustainable Systems Engineering Masters degree. He uses collaborative learning techniques and class exercises to meet his educational goals.

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As sustainability rapidly becomes a much-needed capability in public and private sector organizations, instruction that teaches necessary sustainable competencies is needed to develop an engineering community of practice. The advent of sustainable engineering also requires a broader systems perspective, as well as a more complex system of tradeoffs and priority setting, since systems figure prominently in the issues surrounding resource use, "waste" assimilative capacity, growing population and the ability of current ecosystems to support a quality life.

Unlike sustainable systems engineering practice, competencies used in traditional engineering decision-making are focused relatively narrowly, and this is reflected in traditional engineering curricula. Therefore to ensure that new engineering instruction meets the needs of industry, Sustainable Systems Competency modeling can be used for individuals to develop a systems perspective. This perspective will enable engineers to measure the impact of sustainable initiatives and add value for stakeholders.

This paper will outline the competency model developed for a new Master of Engineering degree program at the University of Wisconsin-Madison, and discuss how the model was used to identify faculty and courses from across the broader campus that would meet the needs of a competency dimension. It will then discuss a new model developed to facilitate better cooperation and revenue sharing between colleges and departments involved in the program, and detail the program development process to bring a new degree in Sustainable Systems Engineering to campus.

Sustainability Competency Models and Curriculum Development

Competency models differ from other approaches to job task assessment because models focus on performance rather than credentials, and define exemplary rather than minimal performance. The value of competency models is to provide consistent and relatively unbiased criteria for exemplary performance in a role or function.[1] Competencies are identified knowledge, skills, abilities and mindsets, evaluated through demonstrated behaviors, which directly and positively contribute to the success of the organization and to the success of employees in their job role, position, or function.[2]

Through interviews with faculty and industrial stakeholders, the University of Wisconsin-Madison's College of Engineering created a sustainable competency model (SCM) for the development of a new Masters Level Degree Program. The model's major dimensions, shown in Figure 1, include science and technology, business and economics, systems analysis, personal effectiveness, working across boundaries, management and planning, environmental justice and equity, and ideas and innovation.

Within each dimension, the knowledge, skills, mindsets and behavioral attributes desired for engineers were further defined. For example, the science and technology competencies represent an advanced understanding and application of scientific principles, engineering constructs, and

technologies relevant to sustainability. Science and technology attributes represent a cross section of basic and applied science disciplines, and describe how competent sustainability practitioners apply these attributes in professional practice. Attributes in this category include understandings of concepts, frameworks, and guiding principles.

Figure 1. The Eight Dimensions of the Sustainability Systems Competency Model Developed for a new Graduate Engineering Degree Program

Typical applications in the science and technology category include the ability to understand and use thermodynamics, and perform engineering analyses of energy use. Other dimensions in this competency are the ability to understand the range of sustainability issues from a local, regional and global perspective, and the relationships between human activities and the environment. Of particular interest is the integration of sustainability goals into engineering practice. Other competency dimensions include the development of expertise in understanding of potential impacts of engineering decisions upon natural and human systems as well as understanding climate change, adaptation, and mitigation to the extent necessary to support analyses, design and policy decisions.

Once each dimension of the sustainability competency model was defined, the desired skills and attributes desired became the foundation for the learning objectives in a new graduate program. The goal of the program was to align the competency model with course development to create a "line of sight" from academia to professional practice. To begin curriculum development, the sustainable systems engineering lead faculty developed a matrix of required competencies compared to courses currently available on campus (Table 1).

Gaps in the competency matrix demonstrated how traditional engineering instruction excluded several elements of the SCM dimensions. These were most notably observed in aspects of the

business practice and economics, management and planning, environmental justice and equity, and working across boundaries competencies. The need for instruction in these competencies necessitated both new course development and a cross-campus collaborative curriculum to build a broader systems approach. For this degree program therefore, lead faculty developed two new engineering courses focused on delivery of foundational competencies. The first course explores aspects of sustainability that affect professional engineering decision-making through the discussion of different sustainable science modules. The second foundational course introduces a range of engineering tools used to apply and interpret the impact of these principles and technologies in the context of sustainability.[3]

Table 1. Course Evaluation Matrix for the Science and Technology Competency Dimension and Four Courses Under Consideration for Program Use

Competency	Attribute	Course 1	Course 2	Course 3	Course 4
Science and Technology	Develop a foundational understanding of essential sustainability concepts and frameworks (e.g. context and key issues from science, political, business and societal perspectives; frameworks for analysis; complexity; and guiding principles)	++	++		++
	Understand the range of sustainability issues from local, regional and global perspectives, and the relationships between human activities and the environment	++			++
	Develop principles, strategies, and methods for incorporating sustainability goals into engineering practice	++	++	++	
	Develop understanding of potential impacts of engineering decisions upon natural and human systems (e.g., atmosphere, water, groundwater, flora, fauna)		++	++	
	Understand and apply the laws of thermodynamics in engineering problem solving	+		++	
	Apply engineering analyses to energy issues including demand, resources and technologies			++	
	Understand climate change, adaptation, and mitigation to extent necessary to support analyses, design and policy decisions	+	+		+

++ = Competency taught and evaluated by application within course
+ = Competency taught but not evaluated

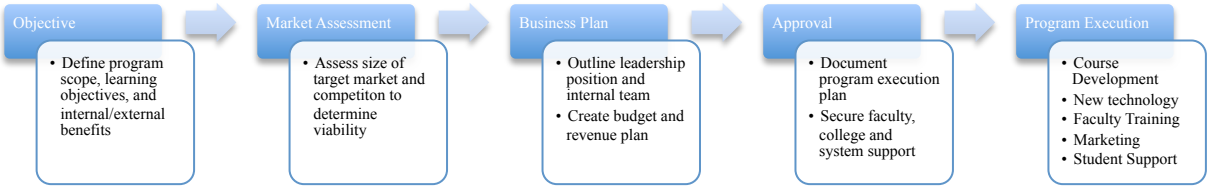
The program then identified that several courses outside of the traditional engineering portfolio would be needed to meet the full range of the desired competencies. To facilitate partnership with these cross-campus departments, institutes and offices that support research and education within the individual competency dimensions, a better model for new program development, faculty engagement and revenue sharing was needed.

Facilitating Cross-Campus Collaboration in new Degree Program Development

Developing a new degree program is analogous to the new product development process in engineering. Therefore a high-level process for development with a number of stop-gate assessment and approval stages was outlined to ensure the program would provide academic benefits and match the long-term needs and capabilities of the college. As shown in Figure 2, the

high-level process begins with the definition of requirements, followed by a full market assessment to determine the viability of the new program.

Figure 2. An Overview of the New Degree Consideration and Development Process



If the target market and benefits criteria for a new degree program are found to be viable, and the business plan defines a position of strength both competitively and financially, the next stage in the development process is to engage the support of the campus and faculty. In the case of Sustainable Systems Engineering, faculty support was needed not just from the initiating department (Engineering Professional Development) for the degree program, but from numerous departments and institutes across campus. In particular, two institutions were approached very early in the objective and market assessment stage for their support as founding partners: the University of Wisconsin-Madison's Office of Sustainability and the Division of Continuing Studies.

Given the degree subject matter, an endorsement from the Office of Sustainability would show an alignment between the program and the campus's plan to integrate and enhance research and education in sustainability science and practice across all parts of campus. The Office was created to acknowledge that solutions to the sustainability challenges of the future require integrated teams and a comprehensive approach. They also acknowledge that addressing these challenges in practice requires an educated workforce trained to consider sustainability broadly, as done in the Sustainable Systems Engineering program. Since the goals of the two programs coincide, a formal partnership would put the new program in a position of strength on campus, and make it more desirable for faculty participation due to the interest and publicity the Office generates.

Another partnership that would promote program support across campus was with the University of Wisconsin-Madison's Division of Continuing Studies (DCS). The mission of DCS is to provide access to educational resources to nontraditional students, lifelong learners, and the community. This partnership was desirable because the early market assessment completed on the degree program found that more than 80% of potential students surveyed identified on-line instruction as a requirement for participation. The Division of Continuing Studies supports online degree program development, and can provide valuable resources for training of campus faculty on the methods for effective distance learning.

After discussion with these two groups that secured their support, the degree's lead faculty mapped a three-stage faculty engagement process (**Figure 3**) for guiding future dialog with potential faculty and departments desired as instructors.

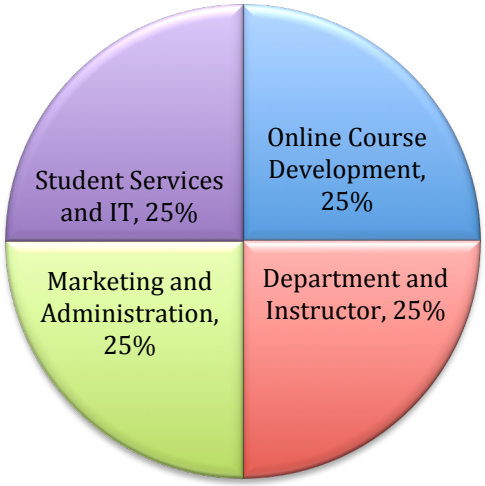
Figure 3. Cross-Campus Faculty Engagement Process for New Degree Programs

<table>
<tr><td rowspan="2">Stage 1: Initiation</td><td colspan="2">Identify Course for Potential Use in a New Degree Program
• Identify an existing course that delivers needed competencies for participation in a new degree program</td></tr>
<tr><td colspan="2">Discuss Faculty and Course Goals against Program Needs
• Department Chair, Program Director, and Learning and Technology Specialist meet with faculty to discuss:
o Program business plan
o Competencies needed vs. course learning objectives
o Financial model for revenue sharing
o Gauge interest in working together</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td rowspan="2">Stage 2: Development</td><td>Discussion of Course Syllabi vs. Competencies
• Program Director and Learning and Technology Specialist meet with faculty to review syllabi and make specific recommendations for strengthening competency instruction</td><td>Discussion of Program Relationship
• Department Chair and Program Director meet with faculty to discuss financial support, teaching assistance and course development schedule</td></tr>
<tr><td>Teaching Delivery Technology
• Learning and Technology Specialist meet with faculty (2-4 times) to supply, train or direct faculty to technology tools and support staff, and provide review as requested</td><td>Formalization of Program Relationship
• Department Chair, Faculty and Faculty’s Department formalize teaching and financial arrangements</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td>Stage 3: Delivery</td><td>Course Delivery
• Learning and Technology Specialist participates in initial course delivery and evaluation to identify improvements or provide technology support</td><td>Working Program Relationship
• Program Director continues regular follow up with faculty on student issues, semester scheduling, finances and future schedule</td></tr>
</table>

An important element of this process was the ability to present qualitative data from the market assessment that would show target revenue estimations. With this estimate, a realistic assessment of revenue sharing could also be modeled. The University of Wisconsin-Madison’s College of Engineering developed a revenue sharing model that uses half of the tuition revenue directly for instructional support, providing a significant benefit to cross-campus departments. One-quarter of the tuition revenue from a course is returned to the instructor’s department, to be allocated at their discretion. An additional one-quarter of the total revenue is used to provide instructors with teaching assistants, instructional design support and technology

as needed for their class. Of the remaining 50%, half is used to administer and market the Sustainable Systems Engineering program, and the remaining funds are kept for future course developments and improvements (Figure 4).

Figure 4. Revenue Sharing Model to Facilitate Cross Campus Participation in New Degree Programs



The result of this revenue model has been greater cross-campus participation, leading to a more flexible curriculum that covers a greater number of sustainable competencies. By working across campus, the final curriculum design included three specializations (energy, facilities and infrastructure) with general interest in sustainable management and policy.

The marketing study conducted prior to program development also revealed a greater chance of success if the program was offered online and with a pedagogical model for interactive distance instruction. The final curriculum design encourages instructors to offer reading assignments or pre-recorded lectures as self-study work to prepare for live class time. Scheduled live class hours are then spent in discussion and application, and not in lecture. Students are also encouraged to work online on team projects for additional interactive experiences, and all students are given instruction in virtual collaboration and communicating technical information.

Conclusion

Through better collaboration with emerging campus centers of excellence in a particular sustainable focus area, a new Sustainable Systems Engineering program at the University of Wisconsin-Madison offers broader systems-based instruction on sustainable tools and practices, while still integrating traditional engineering courses for technical depth. The competency model approach also ensures graduates have the necessary competencies to lead sustainable projects by fully measuring the impact of sustainable initiatives and adding value for stakeholders.

Bibliography

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[3]Eagan et al.