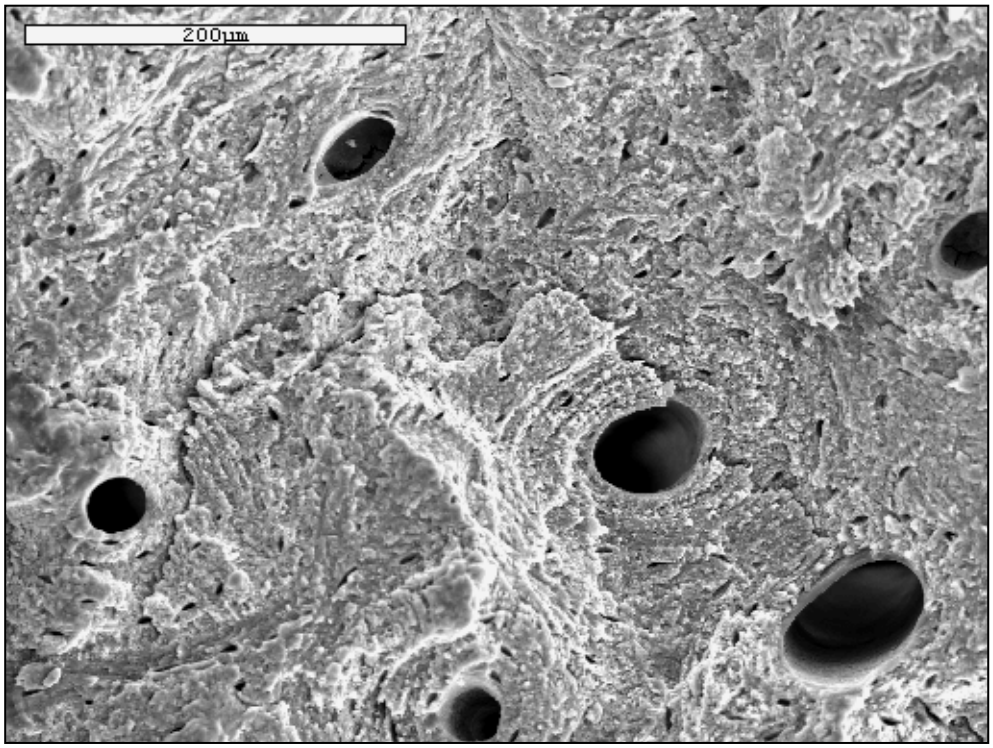
Seventh Symposium on Engineering and Liberal Education



6-7 June 2014

Union College

Schenectady, New York

CAMPUS MAP

Trolley Schedule

Friday 6 June

3:30 pm	Hampton Inn to Old Chapel Circle
8:30 pm	Old Chapel Circle to the Hampton Inn

Saturday 7 June

8:15 am	Hampton Inn to Old Chapel Circle
5:30 pm	Old Chapel Circle to Hampton Inn
6:30 pm	Hampton Inn to Jasmine Thai (2717 Broadway)
9:00 pm	Jasmine Thai to Hampton Inn

On the cover: Scanning electron micrograph of a microcrack in equine cortical bone (photo by Barbara Garita, Ph.D.). The microcrack runs from near the (relatively) large hole at left to the hole at lower right (the smaller holes are osteocyte lacunae, voids in which cells reside that comprise the signaling network in bone). These large holes - Haversian canals - are about the diameter of a human hair and are at the center of an osteon, the remnant of remodeling activity - the internal change of architecture and composition - in this type of bone. Beams machined from the dense cortical shells of horse third metacarpals, each containing a natural hole - the primary nutrient foramen, were subjected to cyclic loading so as to generate cracks like that shown. The architecture near the foramen was shown to arrest such cracks which, if left unarrested, could potentially grow and coalesce to ultimately fracture the whole bone (see, e.g., Garita and Rapoff *Exp Tech* 2003).

WELCOME

Welcome to the Seventh Symposium on Engineering and Liberal Education, hosted by Union College in Schenectady, New York.

We are incredibly grateful to have Dr. Maria Klawe, President of Harvey Mudd College with us to present the keynote address.

We have an outstanding array of papers from researchers and practitioners at the interface of engineering and the liberal arts. We have integrated these papers into an exciting program that we hope will result in you bringing home some practical applications of this work.

On behalf of the Program Committee, we welcome you to our beautiful campus and hope that you have an inspiring symposium.

Shane Cotter, Symposium Chair

PROGRAM COMMITTEE

Chair

Shane Cotter, Ph.D.
Director of Engineering
Associate Professor of Electrical Engineering
Union College

Members

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Associate Professor
Department of Science and Technology Studies
Rensselaer Polytechnic Institute

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Professor of Spanish & Hispanic Studies
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Mechanical Engineering
Union College

J. Douglass Klein, Ph.D.
Kenneth B. Sharpe Professor of Economics
Director, Environmental Science, Policy and Engineering (ESPE)
Union College

Symposium Staff

Karen Crosby, Administrative Assistant for Academic Affairs

ACKNOWLEDGEMENT OF SUPPORT

We gratefully acknowledge the support of the Laurence W. Levine '52 and Barry Traub '53 Endowed Lecture Fund on the Liberal Arts and Engineering. This fund has helped us bring to campus a leading engineer who is also a leading proponent of the liberal arts. We further acknowledge the support of the Union College Office of Academic Affairs.

Special thanks to the Union College Facilities, Media and Dining Services staff, without whom this event would not be possible.

SYMPOSIUM PROGRAM

Friday 6 June

4:00-5:00 pm **Check-in & Reception** *Nott Memorial*

5:00 pm **Welcome** *Nott Memorial*

Dr. Stephen C. Ainlay, President, Union College

5:15 pm **Keynote Address** *Nott Memorial*

"Passion with a Purpose: Using your life to change the world"

Dr. Maria Klawe, President, Harvey Mudd College

6:30 pm **Dinner** *Hale House*

Saturday 7 June

8:30 am **Breakfast Buffet** *Wold Atrium*

9:00 am **Special Session I: The Role of Liberal Education in Increasing Participation of Women in STEM-C**

Moderator: Valerie Barr *Lippman 016*

Despite many efforts over the last several decades, the percentage of women in some STEM-C (Science, Technology, Engineering and Mathematics, including Computing) fields remains low. This session will explore how integrating liberal arts with computer science and engineering course work has succeeded (or can potentially succeed) in encouraging women to pursue work in STEM-C fields.

Panel/Round Table discussion by women majoring in both liberal arts and STEM-C fields at Union College

Liana Nunziato, Samantha Griffiths, Teresa Crasto, SongMy Hoang, Cara Zimmerman

Engineering Meaning: How Smith engineers embrace a liberal education

Borjana Mikic, Andrew Guswa

Liberal Arts & Engineering Studies at Cal Poly – Emergent & Individualized Pathways to Success for Women in Engineering

Jane Lehr, Michael Haungs

We're an Engineering School with Gender Parity - Now What?

Debbie Chachra, Lynn Andrea Stein, Caitrin Lynch, Yevgeniya Z. Zastavker, Alisha Sarang-Sieminski

10:20 **Break** *Wold Atrium*

General Session (2 Concurrent Sessions)

10:45 **General Session IA** *Olin 106*

Engineered Smarter Environment with Human-Like Senses

Ashraf Ghaly

Educating Students on Infrastructure Conceptualization

Berndt Spittka, Steve Hart, Chris Conley

The Wicked Problems in Sustainable Engineering Initiative: Teaching Complex Topics through Shared Resources

Alexander Dale, Justin Hess

Report on the National Academy of Engineering Workshop on Educating Students for the Grand Challenges

Craig Cantello

10:45 **General Session IB** *Wold 128*

Introducing Engineering as a Socio-Technical Process

Kristen Sanford Bernhardt, Benjamin Cohen & Jennifer Rossmann

Engineering the General Education Experience

David Kent

The Integration of Liberal Arts and Technology

Gary Bertoline, Fatma Mili

Integrating Engineering and the Liberal Arts through a Multiphase Capstone Design Experience in Bioengineering

Sudhir Khetan, Jennifer A. Currey

12:00 **Lunch** *Wold Atrium*

13:00 **Plenary Talks: Modules for Liberal Studies in Engineering**

Organizer: Louis Bucciarelli *Lippman 016*

Donna Riley, Dean Nieusma, Louis Bucciarelli

This session will present and critique "modules" – proposed or already deployed in the classroom – for use in a "Liberal Studies in Engineering" program. The idea is to take exemplary, substantive content of the "traditional" undergraduate engineering program – the engineering sciences, the laboratory tests, the design projects – and subject this to study from the perspectives of the humanities, arts, and social sciences. The method is to build on the content and form of instruction in today's engineering program but dramatically transform both content and form to achieve the goals of a liberal arts program – "critical thinking" is the key phrase in this regard – while preparing students inclined toward engineering with a solid basis in the fundamentals of the traditional engineering course of study. To do this, "fundamentals" must necessarily be redefined. An example of a module "Science and the Courts" gives an idea of how a laboratory experiment can be made the focus of liberal studies in a social science course.

14:15 **Break** *Wold Atrium*

Special Sessions II (Concurrent Workshop and Sessions)

14:30 **Workshop Part I:** *Wold 010*
Goethals' Infrastructure Challenge: From Concept to Functional Prototype

14:30 **Special Session II: Modules for Liberal Studies in Engineering** *Wold 128*

Chocolate in my Peanut Butter

Jennifer Stroud Rossman

A Game-Based Approach to Engineering in Context

Kristin Boudreau, Laura Hanlan

Critical Thinking in a Project Based Engineering Program
Robert Grondin, Odesma Dalrymple, Kristine Csavina, Micah Lande

Teaching Science and Technology using Historical/Archival Documents
Maurice Aburdene, Laurie F. Aburdene

15:45 **Break** *Wold Atrium*

General Session (Concurrent Workshop and Session)

16:00 **Workshop Part II** *Wold 010*
Goethals' Infrastructure Challenge: From Concept to Functional Prototype

16:00 **General Session** *Wold 128*

Undergraduate Engineering Students' Understanding of Heat, Temperature, and Energy: An Examination by Gender
Katharyn Nottis, Michael Prince, Margot Vigeant

Fostering a Global Perspective: Incorporating International Case Studies into STEM Courses
Jennifer Rudolph

Global Trends: Strategic Thinking and Systems Analysis for Leadership
Darryl Farber

Rivers and Dams: A multiplayer role-play game that promotes learning in collaboration and team-oriented communication
Ari Epstein, Abraham Stein

The New Sandbox
David Hans, Kevin Buchan

17:30 **Concluding Remarks** *Wold Atrium*

17:45 **Break**

18:30 **Dinner** *Off Campus*

KEYNOTE ADDRESS

"Passion with a Purpose: Using your life to change the world"

Maria Klawe, Ph.D.
President, Harvey Mudd College

Biography

Maria Klawe began her tenure as Harvey Mudd College's fifth president in 2006. A renowned computer scientist and scholar, President Klawe is the first woman to lead the College since its founding in 1955. Prior to joining HMC, she served as dean of engineering and professor of computer science at Princeton University. During her time at Princeton, Klawe led the School of Engineering and Applied Science through a strategic planning exercise that created an exciting and widely embraced vision for the school. At Harvey Mudd College, she led a similarly ambitious strategic planning initiative, "HMC 2020: Envisioning the Future."

Klawe joined Princeton from the University of British Columbia where she served as dean of science from 1998 to 2002, vice president of student and academic services from 1995 to 1998 and head of the Department of Computer Science from 1988 to 1995. Prior to UBC, Klawe spent eight years with IBM Research in California, and two years at the University of Toronto. She received her Ph.D. (1977) and B.Sc. (1973) in mathematics from the University of Alberta.

Klawe has made significant research contributions in several areas of mathematics and computer science, including functional analysis, discrete mathematics, theoretical computer science, human-computer interaction, gender issues in information technology and interactive-multimedia for mathematics education. Her current research focuses on discrete mathematics.

Klawe is a renowned lecturer and has given talks at international conferences, national symposia, and colleges across the U.S. and Canada about diversity in science, technology, engineering, and mathematics disciplines and industries, gender and gaming, and lessons from her own career in STEM industry and education. She has devoted particular attention in recent years to improving K-12 science and mathematics education.

Klawe is one of the ten members of the board of Microsoft Corporation, a board member of Broadcom Corporation and the nonprofit Math for America, a fellow of the American Academy of Arts & Sciences, a trustee for the Mathematical Sciences Research Institute in Berkeley and a member of the Stanford Engineering Advisory Council, the Advisory Council for the Computer Science Teachers Association, and the Canada Excellence Research Chairs Selection Board. She is co-chair of the Scientific Advisory Board of the Simons Institute at UC Berkeley.

SPECIAL SESSION DESCRIPTIONS

SPECIAL SESSION I: THE ROLE OF LIBERAL EDUCATION IN INCREASING PARTICIPATION OF WOMEN IN STEM-C

Organizer: Valerie Barr, Ph.D.
Union College, Chair ACM-W
barrv@union.edu

Despite many efforts over the last several decades, the percentage of women in some STEM-C (Science, Technology, Engineering and Mathematics, including Computing) fields remains low. This session will explore how integrating liberal arts with computer science and engineering course work has succeeded (or can potentially succeed) in encouraging women to pursue work in STEM-C fields.

SPECIAL SESSION II PLENARY TALKS: MODULES FOR LIBERAL STUDIES IN ENGINEERING

Louis Bucciarelli, Ph.D.
MIT (Emeritus)
llbjr@mit.edu

Donna Riley, Ph.D.
Smith College,
driley@smith.edu

Dean Nieusma, Ph.D.
RPI,
nieusma@rpi.edu

This session will present and critique "modules" – proposed or already deployed in the classroom – for use in a "Liberal Studies in Engineering" program. The idea is to take exemplary, substantive content of the "traditional" undergraduate engineering program – the engineering sciences, the laboratory tests, the design projects – and subject this to study from the perspectives of the humanities, arts, and social sciences. The method is to build on the content and form of instruction in today's engineering program but dramatically transform both content and form to achieve the goals of a liberal arts program – "critical thinking" is the key phrase in this regard – while preparing students inclined toward engineering with a solid basis in the fundamentals of the traditional engineering course of study. To do this, "fundamentals" must necessarily be redefined. An example of a module "Science and the Courts" gives an idea of how a laboratory experiment can be made the focus of liberal studies in a social science course.

WORKSHOP DESCRIPTION

GOETHALS' INFRASTRUCTURE CHALLENGE - FROM CONCEPT TO FUNCTIONAL PROTOTYPE

Maj. Berndt Spittka, LTC Steve Hart , Chris Conley, Ph. D.
West Point
berndt.spittka@usma.edu, steven.hart@usma.edu, christopher.conley@usma.edu

Students will do just about anything that is asked of them, if their professors are willing to ask. The Goethals' Infrastructure Challenge (GIC) was designed to inspire students to envision a better future, unleash their creativity, and apply their social, technical, political, and economic skills to address a "wicked problem." The inspiration for developing this new competition was an identified gap in the currently offered Civil Engineering Student competitions and the need to foster interdisciplinary dialogue between engineering and the social sciences. The developers formulated the competition based on proven motivational and education theory. This academic year, West Point in conjunction with several other organizations completed the small and large scale pilot tests the GIC with stellar results. The focus of these pilots was to prove the concept of an online based, open-ended question competition's ability to inspire students to achieve unique and applicable solutions to some of our most complex infrastructure problems, while meeting some of the most challenging ABET student outcomes required of Civil Engineering programs. Using proven metrics for evaluating student performance, the GIC pilots have shown that the nature of Civil Engineering student competitions is only limited by the creativity of those who are asking the students the questions. During these pilots, the students were able, in a four day competition, to create a solution to a wicked problem that encompassed not only a technical solution, but also address the problem's political, social and economic aspects. The results show that once the students are asked the question they will try to (and do) rise to whatever challenge is presented to them. With successful pilots completed, the GIC will be offered nationwide starting in the spring of 2015.

ABSTRACTS

Panel/Round Table discussion by women majoring in both liberal arts and STEM-C fields at Union College

Liana Nunziato, Samantha Griffiths, Teresa Crasto, SongMy Hoang, Cara Zimmerman
Union College
nunziatl@union.edu

We are all women studying English as well as disciplines in the STEM-C curriculum, including Biology, Math, Medicine, and Computer Science. This diverse study gives us many advantages. While studying English, we have developed skills such as writing, editing, analysis and communication, which are all applicable to our STEM-C fields. Through our STEM-C studies, we have learned unique ways to solve complex problems and gained skills in logical reasoning, which is applicable to the analysis of literature. We believe that the contemplation of ethics and morals through the study of humanities enables us to see the ethical standards in research in our respective STEM-C fields. Our liberal arts education has allowed us to develop a wide range of transferable skills. We would like to present how our English training has helped us excel in our respective STEM-C field of study and vice versa. We hope that we can impart the value of an interdisciplinary education that bridges both science and literary arts.

Engineering Meaning: how Smith engineers embrace a liberal education

Borjana Mikic, Andrew Guswa
Smith College
bmikic@smith.edu, aguswa@smith.edu

This May marks the 10th anniversary of the first graduating class of engineers from the Picker Engineering Program at Smith College; the first ABET-accredited engineering program at an all women's college and one of only a handful of engineering programs housed within a liberal arts setting. From its inception, the program has framed engineering as a profession in service to humanity and our curricular approach has emphasized the importance of studying engineering within its larger social, cultural, and environmental context. We will use the opportunity of this panel on the role of the liberal arts in increasing the participation of women in C-STEM to examine the demographic distribution of our students, what choices engineers at Smith make in the non-technical parts of the curriculum, and, more broadly, what the bigger picture stories of student curricular choices might tell us about how they "make meaning" out of engineering. Patterns to be examined include how students choose to satisfy breadth requirements (via distribution across non-technical areas of knowledge vs. minoring in specific non-technical fields), study abroad/away patterns, and how students integrate co-curricular experiences and interests in ways that make each path through the curriculum unique to the individual.

Liberal Arts & Engineering Studies at Cal Poly – Emergent & Individualized Pathways to Success for Women in Engineering

Jane Lehr, Michael Haungs
California Polytechnic State University
jlehr@calpoly.edu, mhaungs@calpoly.edu

This paper describes and analyzes the sex/gender ratio of student recruitment, retention, and graduation in an innovative "liberal studies in engineering" program at California Polytechnic State University as compared to accredited B.S. programs in engineering at the same university. The B.A. Program in Liberal Arts & Engineering Studies (LAES) Program is jointly offered by the Colleges of Liberal Arts and Engineering. The program is designed to prepare students for a wide-range of innovative careers in emerging professional fields that combine skills and interests in the arts, technology, and culture, and for study in diverse graduate disciplines. Internal transfers are accepted into the program from all 6 colleges at the university, including from majors in engineering, the liberal arts, science, mathematics, business, agriculture, and architecture. Students complete rigorous technical education, including 44 units of support courses shared with the College of Engineering as well as the Cal Poly General Education curriculum; 34-35 units of additional coursework in an engineering specialization; 24 units of additional coursework in a liberal arts specialization; and at least 4 courses in Liberal Arts in Engineering Studies: two on project-based learning, a senior project course, and a capstone. Students may also earn internship or co-op credit in LAES. Explanations for sex/gender ratio differences are proposed, including exploration of how the ability of LAES students to design and follow their own unique pathway in this program may disrupt barriers such as impostor syndrome by positioning the student not as impostor but as designer and creator – even when enrolled in courses in engineering in which the sex/gender ratio is skewed male and where non-LAES students from underrepresented groups report greater psychological, social, and educational barriers. Lastly, the paper identifies "lessons learned" from this "liberal studies in engineering" program that accredited B.S. programs in engineering may wish to consider.

We're an Engineering School with Gender Parity - Now What?

Debbie Chachra, Lynn Andrea Stein, Caitrin Lynch, Yevgeniya Z. Zastavker, Alisha Sarang-Sieminski
Olin College of Engineering
debbie.chachra@olin.edu

Olin College of Engineering, which graduated its first class in 2006, has always had gender parity amongst its student body. This commitment is ongoing, so the recruitment and retention of women is integral to the college. With this as our baseline, we focus on understanding the academic and non-academic experiences of our students, on providing them with opportunities to think about and discuss issues of gender and engineering, and to change the culture of engineering. We'll share some of these strategies and approaches, and discuss our common challenges.

Engineered Smarter Environment with Human-Like Senses

Ashraf Ghaly
Union College
ghalya@union.edu

Humans rely on their senses in dealing with the environment around them. Most, if not all, of the products humans use on a daily basis respond to one or more of humans' senses. The sensors the human body can use communicate a sense of taste, hearing, sight, smell, or touch. Engineers mimic nature in their designs and create products that essentially appeal to human senses. Engineering an environment that responds to various phenomena in the same way a human body reacts would be a great feat in engineering design. Such an environment would have the effect of reducing the hazards that Planet Earth presently faces due to out of control consumption and resource depletion. A closely monitored environment through a network of well-designed sensors can make efficient use of available commodities and decrease the effects of natural disasters. Humans have been successful in implementing such strategies on a small scale where, for example, an air condition system make the interior of a building a pleasant place to be even when the outside temperature is extreme. This same effect is almost impossible to reproduce for huge structures, such as bridges for example, serving in the open environment. Sensor technology can help in monitoring the "health" of structures to predict potential problems before they occur. Sensors have penetrated almost every aspect of human life. They can be found in small hand-held devices such as cell phones, motion activated lights inside buildings, and in exterior applications such as e-z pass lanes. These sensors can play a greater role in measuring and recording data. Such data can be instantaneously analyzed by computers provided with algorithms capable of aiding humans in making on-the-spot decisions. The past decade has witnessed sensor technology creeping into many small-scale devices. Based on present indications, the next few years promise to be the era of the proliferation of sensors in large-scale applications. A course addressing the above theme was developed and taught at Union College. Students were fascinated by the possibilities sensors afford to control and monitor interior and exterior environments in pursuit of a smarter planet. The course was well received as indicated by the strong engagement students showed during class discussions throughout the term.

Educating Students on Infrastructure Conceptualization

Berndt Spittka, Steve Hart, Chris Conley
West Point
berndt.spittka@usma.edu, steven.hart@usma.edu, christopher.conley@usma.edu

The ability to wrap your mind around a complex problem is necessary in order to begin solving the problem. In order to allow cadets to begin to understand the wicked problems that are inherent to infrastructure, West Point faculty members have developed and present a set of Conceptual Models in CE350: Infrastructure Engineering. The development of the models was driven by a need highlighted by recent history of Infrastructure failures. On the civilian side the American Society of Civil Engineers and the National Academy of Engineering call for Infra-

structure leadership. On the academic side the constituents of the Military Academy asked for graduates to be able to understand, visualize and describe infrastructure. On the military side the lessons learned from Iraq and Afghanistan showed a need for understanding infrastructure. These models allow students from all disciplines of academic study to quickly and accurately understand visualize and describe the infrastructure they are discussing. The CE350 family of models includes the Component Model, the Assessment Model, and the Resilience Model. Taken as a whole, these models allow students the ability to start to formulate their solutions to wicked problems.

The Wicked Problems in Sustainable Engineering Initiative: Teaching Complex Topics through Shared Resources

Alexander Dale
Engineers for a Sustainable World
atdale@eswusa.org

Justin Hess
Purdue University
jhess@eswusa.org

Modern engineering practice faces a new set of sustainability-related constraints around resource availability, aging infrastructure, and global challenges such as climate change. Many of these challenges have some or all of the characteristics of 'wicked' problems, which lack definitive formulations, include many stakeholders and disciplines, and have better or worse responses rather than right or wrong solutions. Engagement with these problems requires students to consider numerous stakeholders, form a holistic understanding of the system, and to collaborate with individuals from diverse backgrounds in order to develop a meaningful response. Experience with wicked problems in engineering education is critical, but is difficult and lacking at many institutions.

In response to this need, we will discuss the Wicked Problems in Sustainable Engineering (WPSE) multi-university initiative. WPSE provides a community and professional expertise for a shared annual problem each year. Faculty and students across institutions work through distinct components of the same wicked problem in design teams, but have access to each other, professional mentors, and participating faculty through digital environments, creating a multi-disciplinary community. Institutions can integrate the problem content and background modules into existing courses, or offer new courses based on available curricula and syllabi.

WPSE was piloted at the University of Pittsburgh and Rochester Institute of Technology during the Fall of 2014, and the wicked problem students worked through was Roots of Air Pollution. The participating faculty of the pilot run are working with additional schools for the Fall 2015 offering. This presentation will present WPSE as a flexible set of content for use in many different situations. Implications from the pilot run will be used to inform future directions of the program, specifically how it might meet its learning objectives related to critical thinking, developing students' awareness of their professional responsibilities, and students' confidence in working through sustainability problems.

Report on the National Academy of Engineering Workshop on Educating Students for the Grand Challenges

Craig Cantello
Edison Tech Center
president@edisontechcenter.org

This presentation reviews the two day workshop held April 2014 in Washington DC entitled, "Educating Engineers to Meet the Grand Challenges". The Grand Challenges are a set of fourteen goals created by the National Academy of Engineering to address some of the most important issues facing the United States today. The workshop reviewed some of the progress that has been made since the announcement of the Grand Challenges, the areas in which more effort is needed, and held brainstorming to address the needs.

Introducing Engineering as a Socio-Technical Process

Kristen Sanford Bernhardt, Benjamin Cohen & Jennifer Rossmann
Lafayette College
sanfordk@lafayette.edu,

This talk will describe efforts to introduce engineering as an inherently socio-technical process to engineering and other students at Lafayette College. Our efforts comprise an attempt to present engineering as a component of the liberal arts in two ways: one, that it shares creative, innovative, and cultural elements with other liberal arts disciplines and, two, that it is a mode of inquiry and building understanding of the world. Our approach follows from the view that while engineering as a practice is widely understood to include skills in calculation, design, technical dexterity, communication, imagination, values, and social relations, introductory coursework often focuses on engineering in isolation from the larger socio-technical context that holds those skills together.

A focus for these efforts is the piloting of a course introducing first-year students to engineering as a socio-technical mode of engagement. The new course, taught within the structure of a required â€œIntroduction to Engineeringâ€□ framework, develops a socio-technical concept of technology as a system and engineering as a multi-faceted (not strictly technical) activity. This follows from innovations in engineering pedagogy from decades of STS scholarship, and from the emerging field of engineering studies scholarship. This talk will discuss the unique features of this effort at a small liberal arts college, and concludes that the pilot implementation was successful in achieving the desired outcomes. Further, while the authors leveraged institutional advantages, the methods and content should be transferable to other types of institutions.

Engineering the General Education Experience

David Kent
Milwaukee School of Engineering
kent@msoe.edu

The General Studies department at the Milwaukee School of Engineering offers the institution's communications, humanities and social science courses. We're embarking upon a major revision of our four, institutionally required first year courses, incorporating elements of (among other things) experiential and problem-based learning. Using as our design framework the essential learning outcomes from the Association of American Colleges and Universities' LEAP (Liberal Education and America's Promise) project, our goal is to employ as many high-impact educational practices (eg.first year seminars, learning communities, community-based learning, and collaborative projects) as possible. In short, we're looking to push the general education component of engineering education in exciting new directions. We will explore the challenges and opportunities associated with such a major curriculum revision, as well as the possible implications for other institutions looking to re-imagine the general education component of engineering education.

The Integration of Liberal Arts and Technology

Gary Bertoline, Fatma Mili
Purdue University
bertoline@purdue.edu, mili@purdue.edu

There is agreement that something dramatic needs to be done to change Higher Education (HE) in general, the STEM disciplines in particular, and to better serve the needs of business and industry. Reports from various federal and professional bodies have been consistent in their conclusions about the nature of the shortcomings in HE, the substance of recommendations about what needs to happen to redress them, and the sense of urgency for a comprehensive, transformative, and immediate response. The key shortcomings are an outdated HE system that is no longer engaging students, an absence of demonstrable significant learning of the skills needed for the 21st century. The key recommendations call for an overhaul of the curricula with a refocus on the skills needed in the 21st Century (creativity, innovation, collaboration, communication, knowledge fluency, and application), the generalized adoption of empirically validated teaching practices, and the stronger integration of teaching, liberal arts with technical topics, and research. The urgency to take bold comprehensive actions stems from the fact that the incremental approach has been tried for more than a decade and failed to deliver.

In response to the aforementioned opportunities Purdue's College of Technology established an educational incubator that provides a safe environment for faculty and staff as well as key collaborators across the Purdue campus to effect targeted changes on a small scale, test them, refine them, and diffuse them to the rest of the College. Education innovation and transformation will be accomplished by fundamentally changing the learning culture to prepare graduates who have acquired a deep liberal arts education with finely honed technical skills who are better prepared as innovators and "makers", possessing both technical and professional expertise, an attitude of curiosity to learn and connect with others, and the courage to initiate and collaborate for the benefit of society.

Integrating Engineering and the Liberal Arts through a Multiphase Capstone Design Experience in Bioengineering

Sudhir Khetan, Jennifer A. Currey
Union College
khetans@union.edu, curreyj@union.edu

At a liberal arts school such as Union College, science/technology/engineering/math (STEM) students do not have many opportunities to be exposed to the concept of the entrepreneurial mindset, from the perspective of both technology development (e.g., ideation and creativity in the design of a new technology and user-focused design), and technology commercialization. This mindset is particularly important for bioengineers, who work in a highly interdisciplinary field that combines concepts from the physical and biological sciences, as well as other engineering disciplines. It is therefore critical that todayâ€™s bioengineering undergraduates develop a strong entrepreneurial mindset to effect innovation in the field. To address these issues, we have developed a new two-term Capstone Design experience for our senior Bioengineering majors.

In the first of the two terms, completed in March 2014, teams of four students selected and designed a device to alleviate a specific medical problem experienced by a patient of the Center for Disability Services (CDS) in Albany, NY. The second term, currently underway and ending in early June, will allow the teams to continue refining and prototyping their designs with input from the users at the CDS. Supplementing the project work will be workshop-themed lecture content, from guest speakers with the relevant expertise, on topics related to translation and clinical impact of new medical devices or technologies. These topics include regulatory and insurance hurdles, as well as technology commercialization. Finally, in keeping with the tradition of a strong liberal arts education at Union College, the program emphasizes excellence in both written and oral communication. Students are required to assume the role of principal investigator at least twice per term, and provide project updates via PowerPoint presentations and written memos.

We believe this program will foster the professional development of our students as they prepare to entire the bioengineering field.

Chocolate in my Peanut Butter

Jennifer Stroud Rossman
Lafayette College
rossmanj@lafayette.edu

A liberal education introduces a wide range of methods of inquiry: "ways of knowing" the human condition and the world. The methods, values, and history of engineering provide another prism in the kaleidoscopic 21st century liberal education. One engineering method that transcends the practice of engineering is design. Engineering design is an iterative process in which empathy guides the definition and refinement of a "problem," possible solutions are developed and evaluated, and prototypes are constructed and tested, with continuous interaction with various stakeholders. Engineering design's use of collaborative work as an approach, a "way of knowing" through which people with different strengths combine forces to generate solutions not limited to a single lens or perspective, is both a hallmark of liberal education and a transferrable skill that would benefit students from all fields of study. Engineering departments and Colleges can also help graduates of their larger institutions become better technological citizens. Being a good technological citizen means appreciating how technology is developed and distributed; it means asking questions, and understanding where things came from and the processes which led to the current status quo. Even if distribution requirements in engineering do not exist on a campus, it is useful to consider how one might fulfill such a requirement: making engineering methods accessible and relevant to students of all majors becomes a primary goal. I will discuss several examples of this at Lafayette College. In several courses and programs, we endeavor to help non-engineering students gain literacy in engineering methods of inquiry and "ways of knowing," and to learn "Engineering as a Second Language."

A Game-Based Approach to Engineering in Context

Kristin Boudreau, Laura Hanlan
Worcester Polytechnic Institute
kboudreau@wpi.edu, lrob@wpi.edu

The past two decades have seen a transition in expectations for well-educated engineers. Since 1997, ABET has called for "the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context" (ABET 2011). As any city engineer knows after appearing at a public hearing, the technically perfect solution to an engineering problem may be unfeasible for any number of reasons. Furthermore, it's not sufficient to have the correct answer: engineers must know how to form arguments based on data sets and present them persuasively to audiences that don't share their engineering expertise.

For over 40 years WPI has implemented a project-based curriculum allowing students to apply technical knowledge in authentic settings where social context is part of the challenge. However, project-based learning is complex and costly. How can we reach students in institutional contexts where project-based work is impractical?

We report on the first phase of an experiment simulating project-based learning in classrooms through role playing. We investigate the effectiveness of teaching critical information literacy skills through a pedagogical role-play game called "Worcester [Massachusetts] in 1899: The Sanitary Engineering Challenge." This game enables students to explore a historical challenge, understanding it from a particular vantage point through original research; through dialogue and collaboration students then work on a communally acceptable solution.

Our inspiration is the "Reacting to the Past" (RTTP) series of games pioneered by Barnard historian Mark Barnes. Unlike RTTP games, students playing our game must find primary sources, technical papers, and other peer-reviewed literature and incorporate these sources into the game in order to defend their actions and proposed solutions. We describe the development of the game and student assignments and examine a method of assessing the effectiveness of the game in teaching information literacy skills and grasp of historical context.

Critical Thinking in a Project Based Engineering Program

Robert Grondin, Odesma Dalrymple, Kristine Csavina, Micah Lande
Arizona State University
Bob.Grondin@asu.edu

The engineering program housed at the Polytechnic campus of Arizona State University differs in emphasis from most undergraduate engineering programs in several ways. (1) It is a general or multidisciplinary program in engineering. (2) It features a project spine of eight semesters of project work around which the rest of the degree is organized. (3) It has a set of eight program outcomes organized to encompass all 11 of ABET's outcomes a- k, with an additional outcome in critical thinking and decision making. (4) The program has approximately a semester of general electives, courses that can be in any subject of the student's choice: more engineering, more math, more humanities or modern interpretative dance. A consequence of these differences is that the degree could accurately be described as being more liberal in some ways than most engineering degrees.

In the paper we will focus on the critical thinking and decision making outcome of the degree. We will discuss how a project course naturally develops opportunities for the student to engage in critical thinking that are difficult to structure in a course that is defined by its technical content and subject matter. We support the development of these skills with a separate course entitled "Critical Inquiry in Engineering". This course was developed to satisfy a university wide general studies requirement for Literacy and Critical inquiry, for courses that emphasize writing, speaking and the collection and evaluation of evidence. This course will also be described. Lastly, we will discuss how we evaluate our critical thinking and decision making outcome in the framework of our ABET related program review process.

Teaching Science and Technology using Historical/Archival Documents

Maurice Aburdene, Laurie F. Aburdene
Bucknell University
aburdene@bucknell.edu

At its inception, the space program was science fiction come to life, exciting beyond imagination, and each launch pre-empted regular TV programming as an historical event to be witnessed by the nation. Many of today's students see space exploration as mundane, not realizing what a huge accomplishment it represents. By teaching from the original documents, we believe that the "magic" of the moment can be recreated and students can experience the thrill of discovery, and perhaps, be inspired to follow through to careers in science as a result.

This presentation will use the minutes of the Meeting for the Committee on Aerodynamics of the National Advisory Committee for Aeronautics (11/8/1956-11/9/1956) to teach science and technology. The focus is on Project Vanguard, which was first introduced at this meeting, and is presented as the "New Order of Business".

The United States satellite program was sponsored by The National Academy of Sciences, as their part in the celebration of the International Geophysical Year (1957-1958). Vehicle design construction, testing, and launching were carried out by the Naval Research Laboratory, with Glenn L. Martin Company as the prime contractor. The minutes describe the three-stage Vanguard launch vehicles, the purpose of the tests and information to be gathered for refinement of the design, the missile specifications and details for the flight, including launch trajectory, orbit, as well as possible problems.

Undergraduate Engineering Students' Understanding of Heat, Temperature, and Energy: An Examination by Gender

Katharyn Nottis, Michael Prince, Margot Vigeant
Bucknell University
knottis@bucknell.edu, prince@bucknell.edu, mvigeant@bucknell.edu

Previous research has found that engineering students have difficulty distinguishing among heat, energy and temperature concepts, even after instruction. A pattern of females having lower pre-test scores on conceptual assessments than males has also been revealed in physics education research, with this discrepancy being maintained even after instruction. This exploratory study sought to determine whether undergraduate engineering students' prior knowledge of four crucial concept areas in heat transfer significantly changed after instruction: rate versus amount of heat transferred, temperature versus perceptions of hot and cold, energy versus temperature, and thermal radiation. The Heat and Energy Concept Inventory (HECI; Prince, Vigeant, & Nottis, 2009) was used to assess these areas with questions targeting previously documented misconceptions in each area. This study also looked to discover whether there were significant gender differences in engineering students' prior knowledge and their learning after instruction. A convenience sample of 152 undergraduate engineering students from five institutions in diverse locations in the United States participated; 145 were assessed in the first

couple weeks of class, prior to instruction on the target concepts. The students were then evaluated in the last two weeks of the course with the same instrument (n = 142). Females comprised 27% (n = 41) of the sample. Results showed that while participants significantly improved from pre- to post-test, there was a moderate effect and the mean score on the post-test was below what most have considered concept mastery. Males had higher mean scores than females on the total pre-test however; the difference was not statistically significant. After instruction, the mean post-test score for males was significantly higher than that of females. Females did not significantly improve from pre- to post-test. Implications of the findings and suggestions for future research will be provided.

Fostering a Global Perspective: Incorporating International Case Studies into STEM Courses

Jennifer Rudolph
WPI
jrudolph@wpi.edu

This talk examines the value and challenges of using case studies based on material drawn from China to globalize the STEM curriculum at Worcester Polytechnic Institute (WPI) in Massachusetts. WPI has a long history of project-based learning and of sending students to work on projects overseas. However, the on-campus curriculum, like that of many STEM schools, is very much centered on engineering and science in the US. With the help of a US Department Education Undergraduate International Studies and Foreign Language grant, a small team at WPI has worked over the last two years with individual STEM professors (only 1 with any China background) to develop China-related content that advances the technical objectives of an engineering or science course while situating that material in the specific socio-political context of China. The goal is for students on campus, through the use of the modules, to develop broader perspective on their STEM material and engage in comparative analysis that involves the critical analysis associated with humanist or social science inquiry. So far, 5 China modules have been developed for 4 engineering classes and 1 science class. Four of these modules were developed by undergraduate STEM students in humanities courses under the simultaneous guidance of a China specialist (the speaker) and a STEM professor. The talk will cover the advantages and disadvantages of student collaboration in module development as well as the obstacles encountered in acquiring buy-in from STEM colleagues, as well as the use of the modules themselves. China modules at WPI are part of a larger initiative to create a China area studies program for STEM students and as a university-wide initiative to globalize undergraduate education at WPI.

Global Trends: Strategic Thinking and Systems Analysis for Leadership

Darryl Farber
Penn State University
atom@psu.edu

This presentation describes the course: "Global Trends: Strategic Thinking and Systems Analysis for Leadership. " The intent of the course is for students of science, engineering, social science, and the liberal arts to gain a holistic view of the interactions among multiple systems of socio-technical systems that generate the state of the world and possible future states of the world. The course is based upon the National Intelligence Council report, Global Trends 2030, the book Engineering Systems : Meeting Human Needs in a Complex Technological World, and readings that address systems thinking, "wicked problems," and leadership. An overarching theme of the course is that changes in socio-technical systems generate changes in the evolution of civilization and that one function of leadership is to be prepared to act in the face of an uncertain future. Through an understanding of the possible ways the future may become the present, leaders can better understand the implications of alternative courses of their actions today.

Students are encouraged to develop their critical thinking skills such as understanding arguments, questioning assumptions, recognizing that different stakeholders of an issue may interpret the "facts" differently, and asking how parts of a system relate to the whole. Students are also encouraged to think through how systems may fail and why. Finally, we ask the students to recommend ways to manage vulnerabilities, failures, and other risks.

Rivers and Dams: A multiplayer role-play game that promotes learning in collaboration and team-oriented communication

Ari Epstein, Abraham Stein
MIT
awe@alum.mit.edu, stein.abe@gmail.com

"Rivers and Dams" is a multiplayer game designed to help students learn essential elements of collaboration and team-based communication. Originally developed for the University of Georgia's Integrative Conservation Ph.D. program, the game is structured in such a way that it can be used by a wide range of learners in many kinds of settings, including introductory engineering and design classes.

The game is designed to look to players like one kind of game–a game about negotiation, working with multiple stakeholders in large-scale design projects, environmental trade-offs, and related topics–while in fact being a targeted excercise in which players carry out an initial collaboration, reflect on their process and collaboration/communication skills, and then have the immediate opportunity to deepen and cement their learning via another, related collaboration.

Here we present details of the game and its development, along with results from playtesting and initial implementation. The developers would welcome colleagues interested in exploring use of the game in their own classrooms and with their own students.

The New Sandbox

David Hans, Kevin Buchan
IBM
davehans@us.ibm.com, kpbuchan@us.ibm.com

In his collection of essays, All I Really Need To Know I Learned in Kindergarten, Robert Fulghum showed us that we learned how to be creative, share ideas, and work together at an early age. Playing in a sandbox, learning to color (inside and outside the lines), sharing our toys, and interacting with others taught us how to adapt in today's socially connected world.

Today, at IBM, we have not strayed too far from those early lessons. We focus on the 4 P's – Patents, or more specifically Intellectual Property. This is our effort to be innovative and approach difficult issues with a keen eye for change. Likewise, this allows us to focus on customer products, so we design simple and easy-to-use solutions. Papers and presentations are an effective way to continue to develop new ideas. They also help us easily share our experiences. Finally, participating in projects and workgroups allows us to work "outside of our comfort area" to collaborate, share, and grow ideas that benefit the larger community.

What has changed, and what will continue to evolve, are the technology and practices that guide our ability to collaborate and grow professionally. In this presentation, the speakers will explore a focus on skills development—specifically, the 4 P's, and how we are adapting to the challenge of working in a globally connected, digital world. We will also share some real-life experiences, like our IBM Innovation Exchange event, which encouraged a diverse set of team members to play in a "new sandbox". A sandbox that allowed those team members to reach back in time, recall those "ah ha" moments, so they could develop and share exciting and innovative process ideas across professional disciplines.

Notes

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REDEFINING LIBERAL EDUCATION FOR THE 21ST CENTURY

At Union College, we are guided by innovation and inspired by tradition.

Founded in 1795, Union College was the first college chartered by the Board of Regents of the State of New York. We are a small, independent liberal arts college committed to integrating the humanities and social sciences with science and engineering in new and exciting ways. Union's rigorous academics take place in a diverse, welcoming campus environment that supports your personal growth, provides you with a wealth of opportunities to find and pursue your passions, and inspires you to engage with the local and global community through meaningful projects and volunteer work.

At Union, you'll find a vibrant community of learners and scholars, of leaders and change agents—people whose ambition, energy and desire to make things happen are contagious. The intellectual and creative spark can be felt in our academic buildings, Minerva Houses, labs, library, studios and recital rooms—anywhere you go on our historic campus. We have a long tradition of innovation and of educating creative problem-solvers, a tradition which continues to flourish and to define who we are today.

On the back cover: The Union College Logo (top) and Seal of Minerva (bottom). The adoption of the Seal of Minerva at the College's founding was a radical innovation in that it incorporated a French motto: "*Sous le lois de Minerve nous devenons tous freres*"—"We all become brothers under the laws of Minerva".

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