Liberal Studies in Engineering - Workshop Report

Louis Bucciarelli, David Drew, Sheila Tobias

Contents

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Executive Summary

National reports made over the past half century have called for renovation in engineering education. Some argue that the traditional engineering curriculum is too narrowly defined; it fails to address the contexts of practice both local and global and the social, economic, and environmental impacts of innovation. Others note that enrollments in engineering are declining. Many cite the need to broaden participation in the discipline; women, students of color and students from poverty are under-represented. The American population has been changing dramatically, but the demographic profile of engineers has not.

This document reports on the proceedings of a workshop held in Washington, D.C., hosted by the National Academy of Engineering (NAE). The purpose of this gathering was to consider, review, and debate, a proposal by Louis (Larry) Bucciarelli and David E. Drew to tightly integrate the liberal arts and engineering education in a "Liberal Studies in Engineering" bachelor of arts degree program[1]. Attendees included faculty from engineering; faculty from the humanities and social sciences; deans, provosts, leaders from national organizations; and scholars from other countries (Ireland, France, the Netherlands, Denmark, Spain, Singapore).The event was funded by the National Science Foundation (NSF), with supplemental funding by the Teagle Foundation, as well as MIT, and the Claremont Graduate University - the universities of the two co-PIs.

Over a two day period, a series of panels and discussion sessions addressed: the challenges of integrating the liberal arts and engineering education; lessons learned from prior attempts at integration; alternative programmatic strategies and structures; and challenges faced by any initiative which challenges the status quo in higher education.

Lessons from the field.

A cornerstone of this workshop was a series of presentations about ongoing attempts to combine engineering education with the humanities, arts, and social sciences. All Dartmouth students must earn a liberal arts degree; engineering students also pursue a second bachelor's degree through a five year program. Thirty percent of Dartmouth's engineering students are women, more than most institutions, and perhaps are drawn to engineering by the inclusion of the liberal arts. Similarly, Lafayette enrolls many engineering students in a program heavily infused with the liberal arts. Engineering faculty at Brown are exploring establishing a "concentration" in *Liberal Studies in Engineering* in collaboration with faculty from the liberal arts.

- Attrition is not the right word when discussing broadening participation in engineering. A major study showed that women and minorities rejected engineering because they wanted to do something of value[2].

Worcester Polytechnic Institute offers a program - *Liberal Arts and Engineering* - which allows students considerable flexibility in putting together a degree program consisting of a number of courses in the arts

1. A special issue of the journal, *Educational Studies*, devoted to the concept of *Liberal Studies in Engineering* and how it might be implemented as a program of study, is scheduled to be published in the summer of 2015. It will begin with an article by the co-PIs - *Liberal Studies in Engineering: A Design Plan* - and include commentaries by participants in the workshop.
2. The bulleted statements were selected from the many made during the discussion sessions which followed the panel presentations.

and humanities with the same number of engineering courses. WPI requires all students to do an interactive qualifying project and a first year 'Grand Challenge' seminar - both taught collaboratively by faculty from the liberal arts and from engineering. The limited enrollment in the *Liberal Arts and Engineering* degree program is perhaps explained by the flexibility of, and inclusion of the liberal arts in, the general institute's requirements. Modules, learning units that integrate engineering systems with cultural context have been developed and used in core civil engineering courses.

- What decisions will guide the construction of modules, and how will we evaluate the effectiveness of modules?
- Notably, and surprisingly, there was little mention of MOOCs and online enhancement of courses.

The experience of Cal Poly San Luis Obispo is particularly instructive. A first attempt failed. A second attempt succeeded, perhaps because the second planning committee included faculty who were themselves interdisciplinary, had worked outside academia, and had a better sense of what it was like to do engineering. Students are invited to design individual concentrations, e.g. media studies and electrical engineering. Presently 60 students are enrolled in this program.

- WPI and Cal Poly have shown that project-based learning can be an effective vehicle for establishing an integration of the liberal arts and engineering.

Purdue is attempting an integrated culture change, not a piecemeal approach. The focus is on competencies, not course examinations as means for evaluating student learning. This new program presently enrolls 3300 undergraduate early adopters. It's critical that faculty be willing to reform their approach to teaching, e.g., by serving as mentors rather than solely as source of knowledge. Purdue sees outreach to K-12 education as important to attract and prepare students for this new mode of learning.

- We ought not to think of education as transfer of knowledge, but as a process of transformation.
- We want students to say, "I find my mistakes interesting, and instructive". We should be open with our students about what was hard for us as learners.
- Students should be prepared to define problems as well as work on their solutions.

Barriers to Institutional Change:

Will faculty in the liberal arts see Liberal Studies in Engineering as a threat or as a benefit? Internal barriers to program initiation include pride in one's discipline and the lack of a collaborative culture in academia. A major challenge is finding faculty from the liberal arts and from engineering willing to listen and learn the discipline (to the extent possible) of the other. Will *Liberal Studies in Engineering* attract faculty, other than those on the margins, to sustain a program?

- Is there a danger that piecemeal presentation of established theories would oversimplify and fail to do justice to whole bodies of engineering knowledge?
- Engineering faculty define their responsibility as covering well-defined content; if they engage the liberal arts, will they believe they still are doing engineering?

Engineering faculty rarely engage in collaborative, team-based activity - a mode of work so essential to engineering practice. Students need faculty as role models of how engineers behave at work in the world of

business and industry. We must go beyond a style of teaching and advising that reflects engineering's military and scientific roots.

- How much math and science is truly prerequisite to doing engineering?
- Our teaching is all about means to ends, with little attention to who sets the ends.

A main barrier to change is the priority given to instrumental reasoning throughout engineering education. In Denmark, resistance to a new requirement in philosophy delayed its implementation for six years; objections included the usual claims that there is "no need" or "there's no room in the curriculum for a new course". When accepted, the course was often "instrumentalitzed" - made into a study of research methods.

All other professions require completion of an undergraduate degree - some form of major in the liberal arts - before seeking professional training and certification. Engineering differs in that the first professional degree is the bachelor of science degree. Because of this, the undergraduate program is filled with science/engineering core requirements and restricted electives thought necessary to prepare students for practice. This severely constrains educational innovation - one reason for looking to the other end of campus to establish a *Bachelor of Arts in Liberal Studies in Engineering.*

- Under the present system, students must decide to major in engineering before they graduate from high school.
- We should get ABET involved as a cultural partner.

There are other avenues for promoting a smoother pathway into engineering: Consider the so-called 3-2 program offered by many liberal arts colleges. Existing programs at many of the colleges appear to attract few students and only a fraction of students that do enroll go on into engineering at university partly because students perceive that they would have to give up their class affiliation - a form of community.

- Will *Liberal Studies in Engineering* be perceived as a program for the elite?

Opportunities and Strategies for Overcoming Resistance to Change.

The United States offers a richer diversity of higher education forms and structures than other countries and this has strengthened engineering education. How to take advantage of that diversity in promoting *Liberal Studies in Engineering*? A useful model of how a program might be developed is found in the way in which public health has emerged from the shadows of medicine to become a strong and vibrant field of its own. A pre-professional version, modeled on the form of a pre-med program, might prove sustainable especially so if the masters was set as the first professional degree.

Alternatively, consider offering *Liberal Studies in Engineering* as a minor, rather than a major. Another model is provided by the highly successful Professional Science Master's programs, which present business relevant subjects usually omitted from undergraduate STEM programs.

Concourse, an MIT course for Freshmen. emphasizes the value of studying science and engineering mixed with the liberal arts and collaborative teaching. *Liberal Studies in Engineering* might be seen as an extension of this experience upwards, throughout the undergraduate years.

- *Liberal Studies in Engineering* graduates might be suited for a job in engineering/technology even without the master's

To engage faculty from different disciplines, show them that participating in the program will not impede their personal advancement. Transcending silos does not mean demolishing them. Reforms that succeed

respect the past. A new program requires a compelling narrative, a few champions, and a critical mass of faculty. Perhaps begin with an openly experimental, transparent, and inclusive trans-disciplinary research initiative. Faculty can talk endlessly about which disciplines should be engaged and how, but it is more important to develop a critical mass of like-minded people who enjoy working together. A program that needs approvals from more than one faculty will need a supportive home.

- We must think carefully about strategies for faculty development, for example, release time to prepare them for teaching across disciplines, and encouraging professors to sit in on others' classrooms.

The development of *Liberal Studies in Engineering* programs should be driven by optimism, not fear. Focus on what we will gain, not what we will lose, as we move into a new intellectual space. *Liberal Studies in Engineering* provides an opportunity for the liberal arts, where enrollments have been dropping. And make it known that there is a payoff; around half of all engineering graduates eventually find they are "no longer doing engineering". *Liberal Studies in Engineering* would prepare graduates for transition to work in other fields -for life-long learning.

- To become viable, *Liberal Studies in Engineering* proponents will need to illustrate to students, and their parents, the long-term career benefits for gradutes.
- Liberal arts education is not about making a living, but about living.

Liberal Studies in Engineering - Broadening the Path to the Profession
Workshop Agenda

Friday, January 30, 2015 - Day 1

8:00 Continental breakfast available in East Court, outside the Lecture Room

9:00 Introductory Remarks

Welcoming comments from NAE **Proctor Reid**

Welcoming comments from NSF **John Krupczak**

9:30 *Liberal Studies in Engineering:* **Larry Bucciarelli**

The Need for a New Pedagogical Paradigm: **David Drew**

10:15 Coffee Break

10:30 Panel: *Lessons from the field*: Brown, Cal Poly, WPI

Moderator: Alan Cheville

Reports of activities underway or planned, including possible incorporation of a Liberal Studies approach into an existing program - from modules to majors. The focus is on current and future activities, on challenges faced or anticipated.

Kristin Boudreau, Clyde Briant, David Gillette, John Orr

11:30 Open discussion of *Lessons from the field*.

Noon Lunch Seated in the East Court

Advisory Panel lunch meeting in the Board Room.

1:00 Advisory Panel reflections **Jud King**

1:30 Panel: *Challenges in Changing Engineering Education:*

Moderator: Robin Adams

The past few decades have seen significant efforts directed toward the renovation of undergraduate engineering education - emphasis on active learning, engineering design, project and problem based learning, study/work abroad, online enhancement of courses, entrepreneurship, service learning; and we should include ABET's rewriting of criteria for accreditation as part of this picture. In this, efforts to attract a broader spectrum of youth into the profession have been critically important. To what degree have these efforts succeeded? What barriers have they revealed? How does Liberal Studies in Engineering fit into this panorama?

Gary Bertoline, Norman Fortenberry, Sheila Tobias

2:30 Open discussion of *Challenges in Changing Engineering Education*:

3:00 Coffee Break

3:15 Round Table/Open Discussion: *Liberal Studies program scenarios - from modules to majors*.

Moderator: Harry Lewis

We see two key requirements for the design of a program in Liberal Studies in Engineering: 1) exemplary engineering content will be taught from the perspectives of the Humanities and Social Sciences and 2) a sequence of core courses will establish a sense of community among students and faculty. The first requirement may be met through the development of modules designed for infusion into existing or new courses in the Humanities and Social Sciences or in Engineering. The second requires attention to a degree program or track as a whole-- a major. What are the characteristics of a Liberal Studies module? Who will do the teaching? Will collaboration be required? What scenarios describe possible program structures? How long should the program take to complete? Is the liberal arts college which offers a 3-2, or dual degree program a possible venue for a liberal studies major? What about a community college? How much flexibility, elective freedom should be allowed the student? What will graduates be prepared to do? What are the accreditation implications?

David Bradley, Joseph Helble, Jenn Stroud Rossmann,**Jennifer Rudolph**, **Jamie Winebrake**

4:45 Panel: *Liberal Studies in Engineering, the View from Europe*:

Moderator: Steen Christensen (Denmark)

The system for the education of engineers in the EU differs from that in the US - and significant differences exist among countries in Europe. The Bologna Accords were meant to improve mobility. To what degree have they succeeded? Are European Universities and Institutes working to attract a broader spectrum of youth into engineering? What place do the Humanities and Social Sciences hold in the education of the engineer? Are there programs similar to the one we propose? What are the possibilities for a Liberal Studies in Engineering graduate from the US to pursue a masters in engineering in a European university?

Javier Canavate (Spain), Christelle Didier (France), Peter Kroes (Netherlands)

5:45 Open discussion *Liberal Studies in Engineering, the View from Europe*

6:15 Reception East Court

Saturday, January 31, 2015 - Day 2

8:30 Continental Breakfast

9:00 Round Table/Open Discussion**:** *Teaching Engineering from the perspectives of the Humanities and Social Sciences, pedagogical issues*:

Moderator: Jane Lehr

The infusion of exemplary engineering content into a course in Literature or Political Theory might produce a whole greater than the sum of the parts. Alternatively, it might produce a mixture like oil in water. Students may be asked to read Kuhn on Tuesday, then be assigned a problem set the First Law of Thermodynamics on Thursday. How to engage students in reflection on the status of engineering theories? Other subjects presented as a more holistic integration of technology and policy will be essential ingredients of liberal studies in engineering e.g., the effect of the printing press on the spread of ideas and demands for self-determination, but even

here we can move students to reflect on the connections between the instrumental reasoning and tinkering that prevails in the crafting of technology (and in their engineering course work) and broader ways of thinking that rule decision making in society. What has been the experience of workshop participants in this regard?

Brad Kallenberg, Anne McCants, Joe Pitt, Anders Buch (Denmark)

10:30 Coffee Break

11:00 Panel: *Transcending Silos in Colleges and Universities*:

Moderator: Bryan Penprase

Any sustainable installation of a program in Liberal Studies in Engineering will require the backing of administration -- the provost, deans, department heads. It will also require faculty to work across disciplinary and departmental boundaries. Where will the program be housed? Will faculty "lines" be needed? Ultimately, the real test of the Liberal Studies proposal will be based less on the power and clarity of the intrinsic ideas and more on successfully meeting the challenges of organizational change in higher education.

Domenico Grasso, **Jud King, Susan Silbey, Scott Thomas**

11:50 Megan Smith US Chief Technology Officer, Office of Science & Technology Policy

12:00 Open discussion *Transcending Silos in Colleges and Universities*

12:30 lunch

1:30 Wrap up Session: *Next Steps for Liberal Studies in Engineering*

What are some lessons from, and reflections about, the workshop discussions? Beyond the planned feasibility study, what are the next steps in development of Liberal Studies in Engineering programs? What are possible external sources of funding for program development and implementation?

Larry Bucciarelli, David Drew

2:00 Open Discussion *Next Steps for Liberal Studies in Engineering*

2:30 End.

Speaker Summaries

On the 30th and 31st of January, 2015, some sixty scholars from the humanities, arts and social sciences as well as engineering met at the National Academy of Sciences building in DC to discuss the possibilities for establishing an undergraduate, pre-professional degree program — a *Bachelor of Arts in Liberal Studies in Engineering* — meant to attract students undecided about choice of a major who still have sufficient interest to enroll in a program that keeps open the possibility that they might pursue a career in engineering. Attendees included the untenured and tenured, the young and the old, seven scholars from Europe (Ireland, France, the Netherlands, Denmark, Spain); philosophers, historians, classicist, economists, sociologists/ anthropologists, cultural studies faculty, english faculty, theology faculty; Dean of Purdue's College of Technology, the Executor Director, Connecticut system of State Colleges and Universities, several deans of engineering, mechanical engineers, chemical engineers, computer scientists.

The workshop over the day and one half included six sessions, each led by a panel of from three to six project participants panels. The first part of this report contains summaries of panelists' remarks. Members of the first panel described efforts already underway at Brown, Cal Poly San Luis a Bispo, and Worcester Polytech; the second addressed the challenge of renovation of engineering education; the third proposed different scenarios for implementation; the fourth reported on teaching engineering content from the perspective of the humanities; at the fifth, we heard from colleagues in the EU about how the humanities were engaged in their programs in higher education and a final panel explored institutional barriers to change of the sort we proposed.

Each panel was followed by a discussion session. Given this diversity, We were surprised and encouraged by the coherence of these sessions; participants in their comments were, if not on the same page, at least in the same chapter. In the section following this one, we bring to the fore some of the questions and themes which took prominence, threaded throughout, and surfaced at different times during the discussion sessions.

Introductory Remarks

Proctor Reid[3]

Dr. Reid opened the Conference on the first day by reviewing the roles and responsibilities of the National Academy of Engineering and the NAE's especial interest and investment in broadening the pathways to the profession underscoring the Academy's support of the underlying logic and concept of liberal studies in engineering. He particularly emphasized the need to broaden the education of engineers to incorporate ideas and perspectives from other disciplines, including the social and behavioral sciences and the humanities, to enable engineers to understand the social and ethical dimensions of their work and its output. Specifically cited by Dr. Reid was the Grand Challenge of Engineering project, an extracurricular/certificate program to prepare students to work at the overlap of public policy, business law, ethics, human behavior, risk, and the arts, as well as medicine and sciences (now active in 17 schools of engineering). Technical excellence, he concluded, is the essential attribute of engineering graduates, but those graduates should also possess team communication, ethical reasoning and be capable of thinking within a societal and global contextual analysis. He noted that a significant fraction of (U.S.) engineering graduates are not working in

3. A link to the audio file source of the speaker's remarks is embedded in the speaker's name.

engineering. A recent NAE study found engineering graduates to have more varied careers and a more comprehensive view of their careers.

Where does the Liberal Studies concept fit into this mosaic? Broader pathways into engineering and an enhanced curriculum will contribute to recruitment, retention, and even more varied career paths

Pramod Khargonekar

Speaking from his role as the head of the Engineering Directorate, Dr. Khargonekar began by observing that the Grand Challenges of a world population of 9 billion (in 2050) are more than technological problems. They intersect social, behavioral, economic, and human dimensions of who we are. These dimensions include our various identities as individuals and as members of organizations and groups. Our profession – engineering - has an admirable record of having advanced human civilization over the last several centuries. Dr. Khargonekar believes this meeting could meaningfully impact what and how engineering contributes to a prosperous future. We know that groups of people with diverse backgrounds and patterns of thinking, such as those gathered in this workshop, are able to create much better solutions to challenging problems. With this perspective, the idea of *liberal arts in engineering* is truly compelling. Dr. Khargonekar urged the assemblage as it moves to the design stage to take seriously into account, scale, transferability, and adaptability all rooted in articulating and seriously (quantitatively) studying *learning outcomes.*

Larry Bucciarelli

The goal is to establish an undergraduate pre-professional degree program—a Bachelor of Arts in Liberal Studies in Engineering—meant to attract students undecided about choice of a major who still have sufficient interest to enroll in a program that keeps open the possibility that they might pursue a career in engineering. The program's core 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, as well as engineering. It would differ from existing similar programs in that it would include a core sequence of courses required of all students and instill a sense of community among participating faculty as well as students. Think of as a pre-professional program in line with the recommendations of Jim Duderstadt, Jud King, Domenico Grass and Joseph Helble.

The program would provide a smoother pathway into engineering; it would broaden the scope of engineering studies to pay serious attention to the contexts of engineering practice; prepare graduates for life long learning; and provide the student in the liberal arts with a better understanding of the nature of engineering. The curriculum must, at this stage, remain open to accommodate the interests and resources of the schools that take on the task of infusing liberal studies in engineering ideas into their programs; this will vary depending upon the mission of the school, upon faculty interests, student aspirations, and resources available.

David Drew

David Drew discussed educational forces that form the context for this proposal. Much of what we will be talking about at this conference involves creating strategies to attract and effectively present difficult technical material to a wider range of students that we do now. He noted the historical connection to issues raised by C.P. Snow in his 1959 Rede Lecture on The Two Cultures, i.e., the humanities and the sciences. He cited research that showed that many highly talented young people, who would be excellent engineers,

are dissuaded from studying engineering because of the narrow way the field is defined for undergraduates. They seek fields that are more intellectually stimulating. Of particular note is a recent longitudinal study of 12th graders' college subsequent careers, which showed that, while students with moderate verbal and high math skills (as measured by their SAT scores) choose STEM, a group of students we might be most interested in targeting for engineering, having high math and high verbal skills, do not. A clue as to what would attract them derives from an interdisciplinary course at the Claremont Colleges, combining chemistry, physics, and biology, for which Drew serves as external evaluator. He reported that the strongest single predictor of high achievement is a student's verbal SAT. Clearly, there is something about interdisciplinary study that attracts students with high verbal skills

He discussed the large reserves of untapped talent in the United States among traditionally under-represented groups. He cited studies, including his own research, that provide guidelines for removing psychological and organizational barriers these students face and replacing them with strategies that facilitate achievement and success. Institutional buy-in and effective, meaningful collaboration are essential for creating organizational change to broaden participation in engineering education. The next step in the process of advancing liberal studies in engineering will be to conduct in-depth interviews with faculty, students and administrators at selected universities to assess what the climate for change and the barriers to change might be.

Session 1 Lessons from the Field: WPI, Brown, Cal Poly

John Orr and Kristin Boudreau

The first panel began with a detailed history and analysis of a unique program at Worcester Polytechnic Institute which, according to John Orr, a long-time faculty member at WPI, in a period of declining enrollments in 1970, set about upturning their traditional curriculum, and created the "WPI Plan" a wholly innovative curriculum, featuring new courses, an Interactive Qualifying Project, travel abroad to work on practical projects, and a first-year "grand challenge" such as designing systems for feeding the world.

Today, 40 years later, WPI is still committed to the Plan, offering more flexible requirements, new and different majors, and student-and faculty-generated individual projects for 4,100 enrollees. What is unusual and particularly relevant to the meeting are the six required courses and projects in the arts and the humanities, described in some detail by Orr's colleague, Kristin Boudreau. The work culminates in a required "final project", one based in the humanities and including a technical component. She reported on a game developed by students on Worcester's sewage system that successfully mixed ethics, data analysis, and civil engineering as a final project.

WPI also offers a Liberal Arts and Engineering major, WPI's first (and only) bachelor of arts degree. Requirements include nine courses in math and science, nine in engineering and nine in the humanities and arts plus the final project.

This flexibility in WPI's general requirements has served students well: Boudreau related how a student had started a company - a "natural guide" app - as a senior. He had come to WPI wanting to be an engineer; started out in system dynamics, switched to computer science, after a while became a math major; then, eventually, discovered environmental history and flourished. Orr thinks his story illustrates why the Liberal Arts and Engineering program has been a failure because this student *was not* a Liberal Arts and Engineering major! Over the six years the program has been in existence, they have graduated 2 students and now have but 1 student in the program. Students have all the flexibility they need otherwise.

Clyde Briant

Clyde Briant spoke from multiple perspectives: A graduate of a 3-2 combined program he is the self-appointed champion of liberal arts in engineering at Brown University where he is on the engineering faculty. It is important to note, he said, that unlike the other two representatives on the panel, Brown is an engineering school set in a liberal arts environment. His second perspective is from 18 years in industry where he observed how often projects succeeded or failed not because of technical issues but the failure of project personnel to understand different cultures, and to think about aspects of the work beyond the merely technical. Even at Brown, there is a retention issue in engineering, providing him with another challenge. After their first course in engineering, talented students leave the major which has moved Briant to revamp this introductory course.

As for Liberal Studies in Engineering, the program he champions: Even students who do not opt for a Liberal Studies in Engineering program would benefit from having some core courses of this nature. In fact, of the students in Brown's unaccredited A.B. program in engineering, many seem to want to take some engineering but mostly to blend it with another major, such as, in one recent case, a five-year joint degree with the Rhode Island School of Design. Another possible place for Liberal Studies in Engineering is a program of "engaged scholarship" at Brown, which in one instance might involve Engineering and Anthropology; in another, Engineering and Theatre Arts; possibly Engineering and the Humanities. Finally, Briant is looking to connect engineering with several of Brown's policy-based centers, starting with a course in "Appropriate Technologies." One overall caveat: Proponents of Liberal Studies in Engineering need to find ways to engage faculty research in all aspects of the planning process. And one strong recommendation: that the programs coordinate with local high schools.

David Gillette

David Gillette runs the *Liberal Arts & Engineering Studies* program (LAES) at Cal Poly San Luis Obispo with Michael Haungs. Their experience as they put it, "trying something new at a very conservative institution," has been documented in an article in the journal *Engineering Studies*[4]. The problem the faculty originally set out to solve was the drop out rate in engineering which the faculty explained to themselves was the result of too-early selection, too little knowledge about engineering studies and the range of occupations it made available. When a first attempt to put engineering and liberal arts together failed at Cal Poly, a team was put together who were themselves interdisciplinary, had worked overseas, or outside the Academy, and therefore had a better sense of how engineers function in the real world.

LAES has so far graduated 50 students and there are 60 more in the program. The program, housed in both the Engineering and Liberal Arts colleges, is characterized by two innovations: Students' programs are half in the liberal arts and half in engineering for the entire four years of the degree, with the first two years of study nearly identical to the course requirements for all Cal Poly engineering students. LAES students are also invited to design individual concentrations in, for example, music/performance and audio/sound design; media arts, linked up with electrical engineering; computer science and community work, focusing on process management, system design, storytelling and community engagement. A popular concentration is Game Design – either the visual aspects or the structural aspects combined with narrative training from English, Theatre Arts and Communication.

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4. Gillette, D.D., Lowhamb, E., Haungs, M., *When the Hurly-Burly's Done, of Battles Lost andWon: How a Hybrid Program of Study Emerged from the Toil and Trouble of Stirring Liberal Arts into an Engineering Cauldron at a Public Polytechnic,* Engineering Studies, 2014, http://dx.doi.org/10.1080/19378629.2014.944186

Outside funding has enabled the creation of a *Center for Expressive Technologies* and for students' self-created projects, like an archival materials show for the Cal Poly library based upon the Museum of Jurassic Technology in Los Angeles. The student-produced show, called, "Look the Other Way" involved an interactive photography presentation that combined actual archival period images with student-created fake spirit photographs, designed to appear as though they were produced in the same period. The show was designed around a game structure which hid clues in the exhibits that led participants to other locations throughout the library and around campus. To enhance the physical game, the LAES students and faculty also created an iPhone app called "PolyGhost" that led participants to geo-located, ghostly media elements across campus. This game app later evolved into a multi-platform, mobile web application now called, PolyXpress. The PolyXpress system enables "geospatial storytelling" as users walk through historic sections of the California Central Coast, interacting with personal letters, family photos, and video interviews from members of the area's Filipino- and Japanese-American communities, allowing visitors to encounter, first-hand, the previously uncollected histories of these under-represented community groups.

Looking back, why was it so difficult to mount the program? People are afraid of what they cannot see. Once people "saw" the degree of student interaction and community involvement. it made acceptance possible.

Session 2 Challenges in Changing Engineering Education

Sheila Tobias

Tobias laid out three areas of intersection between the goals of Liberal Studies in Engineering and her experience as a STEM education reformer:

First is the issue of math anxiety/math avoidance that leads students to believe they can't or never will master science or engineering. Much of this is the result, she said, of a generalized view that science is hard because it's "hard." To get specifically at "what makes science hard?" she experimented with "outside" populations by removing all the variables to learning science except for "newness to the field." In the one experiment, faculty from fields other than science were invited to try to master a single complex topic in physics (waves in elastic media), or in chemistry (entropy) and to record their difficulties with the assignment. In the follow on experiment, a half dozen graduate students likewise from philosophy, literature, history and even classics, enrolled in Intro Physics or Chemistry for full semesters, attended lectures, did homework, went to labs and took exams in a typical introductory course. Their responses collected into a book, T*hey're not dumb, They're different,* provided faculty readers with real-life exposure to what was not working in their classes. Later she conducted a study of where STEM reform in colleges was actually working, and still later a study of PhD's in the physical sciences who had failed to get academic positions after one, two, or even three years of trying. "Now that you know you won't get a job in the Academy, what do you wish you had studied?" she and her colleagues asked a sample of these failed academics. Their responses: more computer science, more communication, a foreign language, business basics, ethics, added up to a business-friendly science/math master's, which in 1999 was fashioned into the new Professional Science Masters' or PSM.

Starting in 2000, those programs are now 322 in number, in 120 universities, having graduated 6,000 students. Tobias' message: It's possible to invent a new curriculum and see it adopted.

Gary Bertoline

Bertoline is involved in a new engineering technology program, not ABET accredited, at Purdue. He recognizes that changing a culture (of higher education) is difficult. As proof he referred to the well received

study *Rising above the Gathering Storm* which called for radical restructuring of STEM teaching, but which, according to a 2010 follow up, has had little impact, because the nation only tried making incremental change which, according to the Report (and to Bertoline) is difficult to sustain. Instead, he and his colleagues at Purdue are aiming for a *culture change*; not piecemeal and incremental, but integrated. At Purdue, the over-arching theme of engineering today is preparing graduates for the 21st century. One aspect of the change is a new focus on *competencies,* instead of course examinations. Purdue's new integrated program has 3300 undergraduates enrolled, students who have willingly identified themselves as early adopters and are becoming champions.

The major issue in engineering reform, according to Bertoline, is getting accomplished research faculty to think more deeply about what they're doing in the classroom, which leads them in turn to a willingness to look closely at reform. "Flipping the classroom" by which he means a new way of thinking about what should be done before and after class to allow class time to be more active and involving, should be accompanied, in Bertoline's view, by "Flipping" the faculty's focus to teaching. The Purdue program is also targeting non engineering departments which are already mandated to teach engineers. The kind of integration being tried at Purdue involves, for example, persuading the composition department to assign its engineering students to write an essay about a team-based engineering project.

Norman L. Fortenberry

Norman Fortenberry posed several questions: What populations do we seek to engage with Liberal Studies in Engineering? (He noted that, demographically, our traditional white male base is decreasing). If Liberal Studies in Engineering does succeed in attracting students with a broader array of interests, e.g., art history, political science, would not engineering benefit? He observed that considerable effort has been made through K-12 outreach at motivating students to pursue a science and/or engineering degree and that has excited and engaged a good number of youth. But when these students hit "real" engineering classes, they often turn away. Will Liberal Studies in Engineering help keep these students on a pathway to engineering?

And what do we hope to prepare our students for? As former NAE president Charles Vest observed, engineering problems are increasingly complex, of large and small scale. It is essential that engineers be prepared in the social sciences as well as the natural sciences. Norman noted that many engineers, working for firms outside the engineering category, are valued for their skill sets. Should we not explicitly acknowledge and accommodate that fact, tell our students that an engineering education prepares them for a wide range of careers many of which lie outside engineering proper?

Norman went on to describe some of the challenges facing engineering professionals: relatively few are in independent practice as licensed professionals. Those few have incentives to operate as members of a guild, owing their highest loyalty to the profession itself. Many more engineers are employees of mid-size to large firms; as such many feel their primary loyalty is to their employer; and this occasionally causes a conflict of interest. He distinguished between ethical responsibilities of the individual and the ethical responsibilities of the profession overall – former NAE president William Wulf has remarked extensively on this point. A key question therefore is how might engineers in practice responsibly choose among projects upon which they have the opportunity to work?

He ended by observing that most engineering faculty have limited experience working in industry, government, or the non-profit sector. Furthermore engineering faculty rewards are based on solitary achievements, e.g., the publication of papers in journals; rarely do they engage in collaborative, team-based activities of the sort that would be required in practice out in the world (and in research and teaching in

Liberal Studies in Engineering). So how do we, as engineering faculty, most credibly stand as models of the characteristics they seek to instill? “As fish in water, how do we know we are all wet?”

Session 3: Liberal Studies program scenarios - from modules to majors

Harry Lewis

Harvard had an engineering school back in the 1880s when President Eliot – an applied chemist – became president of Harvard. Eliot’s view was that “practical ends” should never be lost sight of in a polytechnic school, but should never be the true ideal of a “College.” Pure science was fine, applied science was not. That view has persisted at Harvard in the term “liberal education”. Lewis himself would love to see Liberal Arts in Engineering succeed at Harvard, but fears his colleagues will be skeptical. On the one hand, engineering faculty is determined that its A.B. in engineering not be labeled “engineering light.” On the other hand, if Liberal Studies in Engineering is installed, the humanities colleagues will fear that Engineering is taking over the last of the fewer and fewer students who choose to major in the humanities.

There’s also some uncertainty as to how STS faculty will relate to such a program, because they too, will fear loss of students. Lewis anticipates two arguments surfacing at Harvard: “We shouldn’t do it” and “We do it already.” (Harvard’s A.B. in engineering is the ABET unaccredited degree). Another factor at Harvard are the General Education course requirements that take up one-quarter of undergraduates’ time, whichever their degree program. General Education courses are largely elective and are not obligated to do the kind of integration across the disciplines that Liberal Studies in Engineering promises to provide.

David Bradley

There are two forces working to bring the arts into STEM (now called STEAM at Vassar). His own is a course in choral music in different architectural spaces, a course that is funded by an outside Foundation. His dual recommendation: that outside sources of funds be apprised of engineering across disciplines and that engineering faculty’s grant writing always include “broader impacts.” The community of engineering has to change its own culture to incorporate broader impacts. There should also be more discipline-based, i.e. engineering education research if we are to create sustainable programs that integrate liberal arts and engineering.

At Vassar, there are two programs for engineering students. One is the dual-degree program, with Dart mouth College. The other, the so-called independent major. Bradley would like to see faculty from the 12 dual-degree programs remaining get together and define a liberal arts engineering degree. Since the liberal arts colleges tend to have few in-house engineering faculty there is another need: for a network of engineering faculty that colleges can tap into for advisers.

Joseph Helble

Helble began by relating that the founder of engineering at West Point, Sylvanus Thayer, was a Dartmouth graduate, and late in his life made a gift to establish an engineering school at Dartmouth. He established the school as a “professional school” that students would attend after completing their basic education, believing it important that an engineering education be deeply embedded in a liberal arts college. This strong association between engineering and the liberal arts is still the case. Every student at Dartmouth who earns an ABET accredited engineering degree has to, in addition, meet all the requirements of a liberal arts education and earn the liberal arts (A.B) degree. This enables students in Dartmouth’s 5 year program – incor-

porating two bachelor's degrees -- to experience the intersection of their engineering program with arts and humanities. Students are told that it's the combination of engineering and the liberal arts that is particularly powerful for their understanding of the world; that the liberal arts degree helps them understand the context for the engineering solutions they will be developing.

The five years that it takes to earn a Dartmouth degree in engineering also provides a soft entry into engineering for students who may be interested in exploring a range of majors at the time of college matriculation. Students at Dartmouth do not choose their major until late in their sophomore year, after they have had some hands-on engineering design and project experience. All this contributes to an engineering student body that has been 30% female for the past decade, and is presently 45% female (current junior and senior classes combined). Fifty percent of Dartmouth students who are not engineering majors take at least one engineering course before they graduate, enabling liberal arts students to experience engineering as part of their education, regardless of major. Ahead is a planned significant expansion of the faculty, in part to provide increased opportunity for all non-majors to get an opportunity to study engineering.

Jenn Rossmann

Lafayette is a liberal arts college 30% of whose undergraduates pursue one of four ABET- accredited programs. Further integration is achieved because engineers and liberal arts majors have a common core curriculum; engineers take 30% of their courses in humanities and social science; and engineers of all types have a common first year curriculum. Jenn Rossmann's personal view is that the liberal arts must include engineering because it, like other subjects in a liberal education, provides students a prism through which they can see the world. Integration of the liberal arts and engineering at Lafayette includes "Introduction to Engineering Design Thinking" which integrates ethics and societal context, with "empathy" as a starting point. The goal is to teach students (of any major) they are problem definers and not just problem solvers. In their strength of materials course, students learn both solid and fluid mechanics in the context of historical case studies; the thermodynamics course includes the history of how this field developed – including all the false starts and "weird" ideas along the way. Mechanical engineering, to take another example, has as an explicit goal to infuse and integrate ethics in engineering – the outcome of a year-long development project.

Another way Lafayette integrates engineering and the liberal arts is in the way it has redefined The Grand Challenge Scholars program to broaden the Challenge descriptions, and recruit/require students from different fields of study to work in multi-disciplinary teams. Among the many engineering courses for liberal arts students are courses "interrogating engineering," and a [David] Billington inspired course in American Studies. External support from Mellon Foundation has enabled Lafayette to support faculty activities outside the usual award structure.

Lafayette also offers a bachelors of arts degree in engineering studies which attracts a more diverse student body. The program has a 45 year history, and offers relevant history, strengths, and challenges to the proposed effort. Courses in engineering economics and policy and in the history of technology enable students to develop frameworks through which to view technology. Bachelor of Arts students have a capstone seminar and project where problem definition is the key.

Jennifer Rudolph

Trained as a political historian of modern China, Jennifer Rudolph believes we need a two-fold approach to liberal studies in engineering. One approach is to use liberal studies to broaden the appeal of engineering beyond its current demographic, and the other, which is more relevant to WPI, is to use liberal studies to

broaden perspectives of current engineering students. This second approach resonates with WPI's efforts to nurture a global mindset on campus and supports its global project centers. Rudolph presented one way that she and colleagues have developed to give substance to the goal of 'globalizing' the curriculum. While WPI has a set of vibrant overseas program for its students (including in China) that can help foster global thinking, not every student, studies abroad. To serve these students as well as those who go to China or elsewhere more formally cultivate global thinking, she has created modules for engineering courses that incorporate Chinese case studies and Chinese data. These modules are spread throughout the curriculum so that students encounter non-US data and contexts in the course of their regular engineering curriculum.

One example is for a 3000 level hydrology course in civil engineering, which now includes quantitative and qualitative data from the Heihe River Basin, home to 1.5 million people, in Northern China. Students use the data and information on water practices and desertification in the area to address water balance issues as well as to analyze water policy recommendations. Students become aware of how differently China and the U.S. deal with water through comparative analysis and in the process start thinking of water issues more globally. Through this and other modules, they learn about the importance of socio-political context.

The modules are interdisciplinary and have been jointly developed by Rudolph and colleagues in Civil Engineering, Electrical Engineering, Environmental Engineering, and Industrial Engineering. Challenges remain, including how to best teach these bi- or multi-disciplinary modules embedded in engineering courses? How to use them most meaningfully? And how to scale them up?

Jamie Winebrake

Faculty don't know what they don't know. Unaware of other disciplines, they need workshops and training. RIT now has a digital sciences/humanities degree –which took four years to get approved at the college level, not yet NY state approval. Speaker is himself cross-disciplinary. He holds a physics degree and a policy/engineering graduate degree. Now Dean of the College, he observes that most faculty have pride in their discipline and asks the question: How to get around those disciplinary barriers and build a collaborative culture? His own efforts began with a gathering of faculty from a variety of institutions in the area to outline a strategy for launching a liberal arts in engineering degree.

Among the internal barriers are faculty's pride in their discipline and the absence of a collaborative culture. Among the external barriers is the President's policy to shorten the time to degree and the national focus on jobs. Our task, then, is to get students, their parents and employers to see that broadening engineering to incorporate liberal studies is the way students can create lifelong careers.

Session 4: Liberal Studies in Engineering, the View from Europe

Steen Christensen

Steen Christensen began the session with what could be a caveat: be careful what you ask for. A new initiative in Denmark was intended to provide more relevance to the profession of engineering. The resulting change in accreditation procedures resulted in a new course that took 6 years to properly integrate into engineering. Resistance took several forms: No need for the new course; no room in the curriculum; instrumentalitze it, i.e. turn it into a research methods course; split it up.

Javier Canavate

Canavate was the first on the panel to refer to the Bologna Process, which was an effort in the mid-1990s to synchronize European universities' degree requirements from the wide variety which pre-existed the unification of Europe to roughly three degrees: bachelor's after three years of post-secondary school; master's after an additional two, and the PhD. In the course of adopting (and adapting to) "Bologna" as it is commonly called, some efforts were made to reduce the entire math/science engineering content in Spain into four years instead of the previous five. Faculty resisted both that reduction and any effort to differently teach or integrate all the required competencies into the four-year curriculum. Coincidentally, in Spain, the humanities came to be increasingly denigrated, seen as "studies for pleasure" or for "hobbies," which means that efforts to implement any kind of new competencies (the kind outlined at this conference) into the curriculum have not yet succeeded. Nevertheless, Canavate believes the regularization of European Universities in the Bologna model will have a positive impact.

Christelle Didier

There are three main types of higher technical education in France: One type focuses on two years training of technicians (not engineers). Nowadays, the best among the graduates might continue their studies in a three-year engineering program. The second form of technical education is the three year engineering school. Entrance requires two years of preparatory classes. Included in this category are the grandes ecoles which, contrary to the french university where any one can go after having passed the high school final exam, are highly selective. To be admitted to a grandes ecoles, students must pass a highly competitive exam. Two years of intense theoretical study (math, science, literature, philosophy, and a foreign language) in small classes where they develop a sense of hard work, sacrifice and competition - very useful in preparation for the study of engineering. The third type, which also leads to an accredited engineering degree, requires five years but students enter the program directly after leaving high school. The two first years of study are very similar to the preparatory classes but without the pressure of the competitive exam at the end of the second year. Most private schools are of this type.

In France, engineering schools have always been strongly linked to their local economic environment. Today's increasingly intense discourse about the professionnalization of engineering education has to be understood in a context where science is no longer called upon to legitimate the prestige of engineering schools and where the rivals on the market of higher education are the business grandes ecoles. Flyers advertising engineering schools and websites focus today, not on science and innovation, but on the international dimension of the school, the non technical experiences, management skills, and the life on campus. This is what distinguish grandes écoles from university; the former are considered too academic and not able to give the students enough experience of team work, active learning, problem based teaching.

France has always been very proud of its grandes ecoles. However, because of their nature and their mission to produce the country's leaders, the Grandes Ecoles have not emphasized research the way the universities do; so while they rank high within the French professional world, they don't rank as high internationally.

Two types of the Humanities and Social and Humane Sciences (SHS) have been a part of engineering education for more than a century:

- an encyclopedic model was meant to prepare the elite, graduating from the most prestigious schools to become gentlemen;

- the second model developed in catholic schools at the end of the Sixth century when the challenge was how to keep society at peace: Engineers were sent to interview poor families and to intern as workers in order to gain an idea of the daily life of those they were called to lead.

A third model developed more recently centered on personal development, entrepreneurship skills, and leadership (following the business schools model): it has become the dominant focus of SHS.

Despite the increased interest in the role of the humanities in engineering education in France, there remains a kind of indifference towards technology and its social impact among students perhaps because of the stress placed upon mathematics and science in their preparation and studies.

Peter Kroes

Peter Kroes was uniquely positioned to describe the integration of a philosophy of engineering course in the Netherlands because he has taught philosophy for engineers at Delft for several years. The tradition began after World War II, when the Technical Universities engaged humanities and social science faculty to provide service teaching for engineers. In the mid 1990s, the departments of philosophy and social sciences merged into "Technology Policy and Management" which today enrolls 250 3-year bachelors' and 150 masters' students at Delft. One might consider it an example of a successful Liberal Studies in Engineering program; but to Kroes it's not. The failing? They approach socio-technical systems in the same way that they approach an engineering system, i.e., in a traditional instrumental way. He sees Liberal Studies in Engineering as being about something else.

It's about *critical thinking* - Engineering is part of a value creation process. What kind of "value" is being produced, and for whom? Instrumental value? Intrinsic value? Social value?

It's about *ethics* in Engineering which includes exposure to the philosophy of science, philosophy of technology; moving from problem solving to problem diagnosing. "Problems do not fall from Heaven." They have to be identified and defined. He stressed the need for co-development by philosophers and engineers of these courses.

He then described two problems relevant to establishing a *Liberal Studies in Engineering* program. Where do you find the engineering professors to co-develop and co-teach, especially when they claim they have not enough time nor the expertise? The academic rewards system doesn't work this way and it is harder work. It requires more than reading a book. The second problem, the other side of the coin: Where to find staff members in philosophy and social science who take technology seriously and are willing to spend their life analyzing technology and willing and able to team up with engineers in the classroom? Kroes solution: hire staff with a double background - people able to speak both languages - but today such people are hard to find.

Session 5: Teaching Engineering from the Perspectives of the Humanities and Social Sciences: Pedagogical Issues

Anders Buch

The discussion was supposed to be about pedagogy, namely teaching engineering from the perspectives of the humanities and social sciences. But inevitably we have to discuss the meta issues. Pedagogy does not

exist in a vacuum. As Anders put it most dramatically, “What we are trying to change is how engineers do their job. So education is only a means to an end of how engineers practice their trade.”

He elaborated: In Denmark there are some progressive engineering programs that have actually tried to bring in liberal studies in engineering. Professor Buch has followed some of those graduates to see how they have fared. They were trained in problem-based learning for collaboration and innovation; in real world problem solving; to favor sustainable solutions; in holistic practices and interdisciplinarity. But in their work place, they encountered the opposites: profitable, instead of sustainable solutions; coordination, not collaboration; standardization of work processes, especially for new graduates. Not holistic approaches, but fragmentation. What to do about the disconnect? Buch recommends *both* taking into account actual practices in the engineering workplace and working to change these.

Brad Kallenberg

Brad Kallenberg comes from a unique background with distinctive cross-disciplinary sets of skills. He majored in physics, worked as an engineer; then turned to campus ministry and has published a book of essays on *The Role of Engineering at Catholic Universities*. He teaches a course in ethics to engineers, called “Ethics of Design” at the University of Dayton.

The course enrolls 20 students, half in the humanities, half in engineering. The way he structures the course is as if the students in teams were actually real design firms, competing for contracts. His point is this: Liberal arts is not just a style, a method, or an approach. There’s also content. So a liberal studies course in engineering has to do more than import a perspective; it has to illustrate that perspective at work: in cross-domain transfer. As an example, he uses the Wright brothers approach to powered flight. As bicyclists, they realized steering had to be structured to work in three dimensions (involving intentional weight change). Others had sought to design steering as if for an automobile. Steering with their hips gave them their breakthrough. Kallenberg will turn next to a cross-disciplinary course for students at Dayton in ‘What’s wrong with manufacturing”.

Anne E. McCants

In addition to teaching history at M.I.T., Anne McCants directs the *Concourse Program* at M.I.T. - a freshman learning community, which covers the freshmen’s science core within a humanistic/social science context. In that program and elsewhere in her teaching, she tries to convey the difference between science and engineering: Science is a process of discovery; engineering a process of solving a problem. Both, she tries to impart to her students -- and this is what makes hers a liberal studies perspective -- are critically dependent for their diffusion on communities of believers. To be successful, whether a scientist or an engineer, one has to be persuasive (convincing) to the peers in your environment. This makes a liberal studies in engineering perspective useful as well as desirable. Intellectually, it helps students distinguish truth claims from the realm of simply making artifacts; second, it provides the social and community context through which others can connect. Trade-off calculations is a specific case in point: how to think about trade-offs, how to communicate their benefits and costs, how to persuade people.

Another course, co-taught with Susan Silbey in anthropology, covers social science research methods, getting M.I.T. students to think about engineering system design: how engineers think, how to set up a research project, how to write a paper with someone from a different culture. A third undertaking is a course on the *History of the Book* in Europe and East Asia from Gutenberg to the present, which will eventuate in the building of a hand-set printing press.

Joe Pitt

Joe Pitt has been teaching at Virginia Tech for 44 years during which period the university enlarged from 4000 enrolled students to 31,000. For a while Agriculture was the main draw; now it's Engineering. Unlike the other majors on campus, engineering students only have to take engineering courses and satisfy the university-wide core curriculum., which requires 36 hours of courses spread out across seven areas including 14 hours of math and science. No further requirements outside of engineering. One course he teaches at Virginia Tech is an Introduction to Philosophy, which enrolls 300 students. Another is Philosophy of Technology, with an enrollment of 35.

His goal is to get engineering students to *want* what the liberal arts have to offer. They won't be doing engineering life long. They may change fields, move into sales or management, or both. And the liberal arts courses are good preparation for those moves. As for pedagogy, the best way to learn, he finds, is through student presentations, enabling students to learn from one another. This modality also increases the intensity in the class, particularly among students from different disciplines. Pitt is not trying to create whole new programs. Rather, he wants his students to figure out for themselves that there is value in studies other than engineering.

Jane Lehr

From her vantage point as a liberal studies faculty member at an engineering institution, Jane Lehr offered some general observations and advice about integrating liberal arts courses and experiences into an engineering program, particularly one, as at Cal Poly, that allows engineers *no free electives.* Coming as she does from gender and women's studies and STS, Lehr is herself having to cross disciplines (learn computer science) in order to co-lead a four-week "Global Engineering" research expedition involving robotics, computer science, mapping and tunneling on the island of Malta. Her recommendation to the Liberal Studies in Engineering assemblage is not to dismiss the Minor as a vehicle for providing liberal studies in engineering. Her students who are minoring in Gender Studies at Cal Poly develop an enriched understanding of social science as well as a strong affiliation with the department.

Session 6: Transcending Silos in Colleges and Universities

Bryan Pemprase

Brian Pemprase began the discussion by challenging the term "silos" to denote the nature of a discipline or a field. Each field, he said, has a "defining culture" and young faculty in particular feel that culture as the *surface gravity* of their department, enabling them to publish and to proceed professionally. Continuing the metaphor, he agreed that there are places in the universe where planet gravity can be shared or counter balanced and charged his panel and the audience to identify these spaces, such as field programs, and find ways to incentivize collaboration.

Jud King

King saw his charge as being to explain how change is achieved in universities. He began by pointing out that one of the country's great assets is that we have many different kinds of institutions of higher education which means that the way change is achieved will vary greatly from one institution to another. That variety is reflected in the schools represented at this workshop - technical universities and liberal arts col-

leges - institutions with different traditions for accomplishing change and different too from large comprehensive research universities. There are a number of things to deal with in all cases.

A common factor is that the faculty controls the curriculum - not the administration, not one faculty, but the faculty as a whole have to collectively agree to change.

There is another simultaneous need for accomplishing the change proposed: We have to build a bridge to bring engineers and humanists and social scientists together to create a common understanding of goals and objectives. That's not at all simple. Participating faculty will have to see that participating in the program is not going to impede their personal advancement – advancement which is traditionally so departmently centered.

Likewise, there is the need to assure graduates of these programs that they will indeed have opportunities go forward with the new degree, either in engineering or in another field. There need to be a variety of opportunities of this sort, including finishing an engineering degree.

Important for this new degree program is that it have a supportive home, either in a department or a college; or in a strong interdisciplinary studies program since curriculum and budget - probably with a whole new budget, which will need approval from more than one faculty. The program description at times speaks of a degree program duration of three years – an additional controversy with which we may not want to deal as a further complication.

What worries him overall about implementation a liberal studies in engineering program is that all of these changes and approvals have to occur simultaneously, which leads him to thinking about how we might proceed to gain much of what we seek with fewer simultaneous changes required. He concludes that it might be best to model new programs on programs already in existence at universities, like Dartmouth, Harvey Mudd, Smith, Yale, and Harvard, all of which offer B.A. degrees in engineering.

Rather than having to gain acceptance of a degree, a curriculum, and a program, he speculated, would we not be better off emulating medicine and law and creating a set of courses that should be taken in the undergraduate years as a preparatory path for engineering within any of many possible existing undergraduate majors? In this case only faculty of engineering would have to sign on to this new path. He would sell the program to engineers claiming the program would expand their sources of good students. The advantage is that a pre-med-like curriculum, consisting of a set of courses that would satisfy entry requirements for certain programs in engineering, would be easier to field. The disadvantage would be the loss of a focused integrated experience in engineering (but however there would be such an experience in whatever was the undergraduate major chosen), but the differing undergraduate majors would bring in a set of students with a richer and more diverse set of backgrounds. Note that pre-meds can major in almost anything and still get into medical school.

He urged workshop attendees to work to get engineering courses incorporated into the general education requirements of the University. The time is ripe. But there is a problem in that there are presently few, if any, engineering courses of a nature such that they would serve this purpose well. A general education course would have to be different from the standard introductory course in engineering designed for students on a path to a degree in engineering. Standard introductory engineering courses are not usually good enrichment courses for a student who is going to take it as an isolated course satisfying a general education requirement.

Courses of this kind have developed, in his experience, when the very existence of an engineering program was threatened by low enrollment. Such was the case at Yale when, in order to survive in the face of too

few undergraduate student majors engineering faculty had to develop general education courses to gain course enrollments, and they did so very well indeed, generating a lot of enrollment. So we might look toward engineering departments that might want to save themselves by responding to the call for the development of general education courses.

Domenico Grasso

Domenico Grasso began by agreeing with Brian Pemprase in urging the assemblage not to diminish but to respect silos. When we talk about transcending them, it should be clear that we are *not* talking about demolishing them. They have value. His recommendation for initiating any new program is to start with a compelling narrative, find one or more champions, then seek to assemble a critical mass. For starters, seek seed funding for what is called a "trans-disciplinary research initiative" one that is openly experimental, transparent and inclusive. The goal is to have this initiative evolve into curriculum reform, but it should not start out this way. Reforms that succeed, he advised, respect the past. They seek to be seen as the next step in the saga of the particular university; not as a repudiation of the past. Two existing mechanisms are "strategic planning" and "Academic Program Reviews". Both engage faculty in thinking about the future. An example is the new strategic plan at University of Delaware, denoted as "Delaware Will Shine" with subgroups called "Grand Challenges, "great Debates" and Big Ideas.

In that connection, Grasso advised that engineers (and by extension engineering educators) talk about how engineers will engage in the great debates of our times and by extension which content and pedagogy is most likely to cause that to happen. He referred in closing to public health as a model. Public health first started as a "step child" of medicine and is now a graduate specialty in its own right.

Susan Silbey

Much of what we've heard so far, Susan Silbey began, focused on topics generic to higher education: sorting of students, setting of choices, pedagogy of the classroom, mentoring, in the context of competing values of students and faculty, Additionally: tenure research rewards, incentives, difficulties of collaboration across disciplines, difficulties of institutional change, and the gap between what is taught and the culture of actual work in the work place.

None of this has to do with engineering per se. What we should be talking about is the characteristic of engineering that is unique to engineering, namely the four-year professional degree. All the other professions require the completion of an undergraduate degree before students are given training in their expertise. That engineering is a four-year professional degree has enormous consequences for our discussion: The four-year degree makes engineering a magnet for those for whom college must provide an occupation, that is, first-generation college students who can't afford to go to college and not become qualified for a job immediately afterwards. In France, she said, referring to an earlier panel, students treat their education as a tool for upward mobility, not cultural enhancement. A second effect of the four-year degree is that faculty feel the need to pile on more courses to prepare students; not like faculty in other fields who believe their task is to "light a fire." This leads to a third effect (of the four-year degree): engineering continues to suffer a lower status (not having a post-graduate program and not including the liberal arts). Silbey thinks this is reflected in frequent calls for change in engineering, and resistance to anything that could be deemed "engineering light."

Scott Thomas

Although he, too, is a sociologist, Scott Thomas wanted to focus less on what can be done on a campus than what can be done on a macro level, specifically how fields became more and more specialized and professionalized, super-ordinate to what happens on campuses. Change he implied has to begin with how graduate programs train and control the faculty, who eventually deliver the undergraduate engineering curriculum. Discipline level norms typically transcend institutional norms. His point of view comes in part from the fact that at Claremont Graduate University, being small, faculty and administrators have to play multiple roles. As this pertains to engineering education, if we ask faculty to behave differently from what is valued in the disciplines, that is, integrating liberal studies and engineering, the experiment may not work. It might attract faculty who are too senior or at the margins of their disciplines, but not the vibrant center of the university whom we need to enlist. He concluded where he began: "Until things change in the socialization of emerging faculty, in the content and processes defining our graduate programs, we should not expect significant integrative change (scale change) at the undergraduate level."

Wrap-up Session: Next Steps for Liberal Studies in Engineering

Gary Downey

Gary elaborated on his invitation to workshop attendees to comment (1000 words or less) on the paper by Bucciarelli and Drew, *Liberal Studies in Engineering* which will all together - paper and responses - make up the entire inaugural issue of *Issues in Engineering Studies* of the journal *Engineering Studies*.

Downey began by explaining why he decided that a new organization and an affiliated journal made sense as a way of contributing to the design process for a bachelor of arts/liberal studies in engineering program. Referring to the original charge by the conference organizers, this phase has been characterized by brainstorming with a first feasibility study down the road. Downey's challenge: how to share the excitement present in this meeting.

The 1,000 word response is meant not just to give participants the opportunity to reflect upon what transpired at the workshop but to enable them to write more extensively about what they themselves are doing vis a vis integrating the liberal arts and engineering. He encourages authors to report how they are conceptualizing what they are doing and describe the barriers they are confronting. The goal is to enable communication across the spaces that separate the participants.

Hopefully, he concluded, this Workshop has demonstrated that liberal studies does not lack content; nor is engineering homogenous.

David Drew

The College of Engineering at Harvey Mudd, which was invited to send representatives to this meeting but could not come, is a wonderful illustration of an attempt to combine liberal arts and engineering.

Of the several multidisciplinary environments in which Drew has worked, one, the Department of Social Relations at Harvard, never really achieved the integration of the fields of clinical psychology, social psychology, sociology and anthropology, and, as a department, no longer exists. The Rand Corporation, where he also worked, tried to structure a matrix with columns designating departments and rows designating research programs (defense, health, education). The relations that developed among researchers, however, often defied these categories. People worked with people they wanted to work with, corresponding to Jane Lehr's comment about students identifying with their minor program and not their major. We can talk the-

oretically about which disciplines should be combined and how. But more fundamental to the task at hand is how to develop a critical mass of like-minded people who enjoy working together.

One way is to examine successful integrations of separate disciplines. Brian Penprase in his own work created a new subdiscipline of anthropological astronomy tracing how different cultures through the ages have viewed the skies. Another new field is inorganic biochemistry, tracing the effect of inorganic materials on human biochemistry, that came into being as the research required.

Drew outlined next steps for *Liberal Studies in Engineering* as starting with Gary's inaugural issue of the journal *Engineering Studies,* with a report of this meeting, followed by a major feasibility study. But the impetus for program development should really come from the colleges and universities themselves.

Ray Fouche

Ray Fouche graduated from college with a degree in the humanities but only one course short of a degree in chemistry. His doctorate was in the field of Science Technology and Society and he has taught product design innovation at RPI and managed an interdisciplinary program at the University of Illinois which featured multilevel design projects. He is, as his intellectual biography and his current position attest, very interested in relationships between the two worlds of engineering and the liberal arts. Upon returning to Purdue after the Conference, he wants to pitch a new idea to his Dean for which he has been working on a "compelling narrative." He plans to begin with a discussion of the Grand Challenges. To wit:

Grand challenges are always as much scientific as technical, as much social as practical and conceptual an always interdisciplinary. In developing a place for the study of engineering in a college of Liberal Arts, the precise configuration will have to relate to the local environment and to the challenge of becoming less invested in disciplines, more exploratory and thoughtful. How can this project (like the one he is trying to pitch to his Dean) be driven by optimism instead of fear? Instead of thinking about what are we going to lose, why not about what we are going to gain as we move intellectually to a new space and new claim? Liberal Studies in Engineering, it can be argued, will provide an opportunity for liberal arts where enrollments are dropping. Just as "Biology and Society" is attracting premed students as they are finding it gives them leverage in applying to medical school.

Diane Michelfelder

Diane Michelfelder began by describing Macalester College as having no engineering degree program at all which gives the faculty a certain kind of freedom. They don't have to worry about moving engineering into the liberal arts or the liberal arts into engineering. What Macalester does have, at least on its books, is a 3:2 program which exists, she said only "in words" in the catalog. No students have enrolled in the program in many years for a variety of reasons: a high number of students at Macalester are on financial aid and it is never easy to port financial aid to next university. Also, 3:2 students perceive that they would have to give up the community of their class affiliation.

So she is interested in exploring alternative pathways. Despite lack of interest in the 3:2 program, Michelfelder indicated, students interested in engineering do come to Macalester. Absent engineering, they often major in physics. And she believes there might be interest in pre-engineering along the lines of premed or pre-law, or a concentration, a curricular pathway at Macalester that functions as a hybrid between a major and a minor. One outcome of her participation in this meeting is a plan to have her colleagues at Macalester get together with advisers from other 3:2 programs (also on life support) to brainstorm for alternative pathways to engineering.

Discussion Sessions Narrative

Liberal Studies in Engineering - a pre-professional program.

Liberal Studies in Engineering program might best be viewed as a pre-professional program - fitting the vision of those who hold that the first professional degree in engineering should be the masters. Engineering is one of the few professions which requires but a bachelor's degree to enter practice. That may be viewed as a good thing. But the other side of the coin is that students have to decide to study engineering *before* they graduate from high school. (Orr, DS 1, 08:08)[5].

Leaving aside the question of whether "liberal studies" is the right choice of words - the label was both questioned and endorsed (Lewis, Orr, Bristol, DO 2) - the discussion included conjecture about what graduates might do if they *did not* pursue an engineering degree. Recall that students with interests beyond the possibility of a career in engineering will be welcomed. Without some veritable story about life beyond graduation, *Liberal Studies in Engineering* is liable to become a "boutique program" (Jones, DO 2, 7:17). And we need to pay attention to what parents might think; if they perceive Liberal Studies in Engineering as an intellectual exercise, we may attract only a few students (Helble, DS AP, 01:56)

One of our European colleagues called into question the need for an "elevator pitch" that explained our objectives and the ways we would accomplish them; he found this too one-sided, "instrumentalizing" what we were about; he saw value in *knowledge for its own sake* (Kroes, DS AP, 00:43). Another of our European colleagues reported that students want an education directly linked to employment and asked if liberal studies would not be viewed as a program for the elite, even if not intended as such (Christensen, DS 4.1 04:33). We suspect that those who read what we are about this way believe that the liberal arts is only for the brightest, the privileged, the Harvard legacy. Liberal studies in engineering means to challenge that way of seeing.

Some claimed that graduates might be well suited for jobs in technology without the masters. Industry likes the hybrid nature of the Cal Poly Liberal Arts and Engineering graduate (Gillette, DS 1, 17:46). We need to get rid of the mythology prevalent among our engineering faculty colleagues that technology companies only want to hire engineers (Lewis, DS 1, 04:47).

Several observed that many engineering graduates move out of engineering into other jobs, other careers, at some point down the road. In a study by Marie Thursby, a Regents Professor of Business at Georgia Tech, of 12.6 million graduates with science or engineering degrees, only 3.9 million worked in science or engineering jobs[6]. Northeastern University did a survey of teenagers entering engineering. Most of them thought that they would, upon graduation, be working for themselves. Anecdotal evidence from returning students was that "most of my friends are no longer engineers" (Boudreau, DS 5.2, 10:08). A design objective: make liberals studies in engineering a program that reflects and prepares students for what most of these graduates actually end up doing. It's not a sin to prepare for an engineering career and do something quite different from engineering; our engineering faculty culture constrains us to think that if you graduated in engineering and are no longer doing engineering "you have left the priesthood" (Pister, DS 6.2

5. "DS 1" refers to the file "Discussion_Session_1.mp3"; "DS 4.1" to the file "Discussion_Session_4.1.mp3"

6. Thursby, M., "The Importance of Engineering: Education, Employment, and Innovation", *The Bridge*, Fall, 2014

07:00). We should set up alternative career fares. Bring in the kinds of companies that seek the kinds of students we want to educate via liberal studies in engineering (Bourdreau, DS 5.2, 10:08).

These observations prompted questions about the worth of the traditional requirements of an accredited engineering course of study: was the weight given to math and science excessive; did students really need all that math (Heywood, DS 2.1, 05:55)? One participant thought not; the requirement was an artifact of the engineering faculty culture living in the past (Orr, DS 1, 08:08) Mathematics is certainly useful and important but will not suffice in practice (Downey, DS AP, 13;39). Data was presented that showed how, women graduates of Smith, Olin, MIT and UMass, who had transferred to another major out of engineering earned significantly more than men who had completed an engineering degree. Women are being rewarded in the market place for having some technical education (Silbey, DS 4.1, 09:23). If one insists on a utilitarian perspective in evaluating the worth of an educational program, then one might ask how these math and science prerequisites contribute to the professional development of the student. Or are they justified as *knowledge for its own sake*?

The purpose of higher education, of undergraduate engineering education.

The emphasis of Liberal Studies in Engineering should be on individual growth, not on job training (Pitt, DO 2, 14:55). But individual growth for what?

Students should be prepared to define problems as well as work on their solution (Harris, DS AP, 02:46). This is particularly urgent in this day and age when the challenges society face are so complex, of such scale, so rife with social- cultural as well as technical ingredients, a complex unimaginable but a few decades ago. Yet we can learn from history: the history of civil engineering reveals the rivalries between engineers in a political economy. Our students need to learn about the world of business; we need to move them to talk about these things, about our infrastructure today, the importance of politics so inherent in all the so-called "grand challenges" we face. It's easier to talk about engineering and politics in a historical context (Jackson, DS 5.2, 12:43) There is a special need for graduates to be prepared to address "socio-environmental" ecological challenges amidst a destabilized climate. While implicit in our purpose we should make an explicit claim in this domain - it's a branding issue (Jeremijenko, DS 2.1, 21:54).

Utilitarian ideals have always defined, in the main, the purpose of engineering education. That is, the purpose of engineering education is to prepare the student to get a job, run a business, make lots of money. Today, utilitarian motives rule like they have never done before (Heywood, DS AP, 04:43) and this is true beyond the walls of the engineering classroom. Jamie Dimon, speaking at Davos, reportedly suggested that universities should get rid of the humanities; and Grove of Intel saw no need for attending to "values" in education. It was like Grove was saying "give me a person who can code; put him/her in a cubicle, then discard after they burn out in a year "(Bristol, DS 4.1, 07:22)

Liberal Studies in Engineering should aim to make engineers who think of themselves, not as cogs in a machine, but as leaders - members of society with a larger role to play (Krieger, DS AP 08:40). We were reminded that universities in the US were founded for a public purpose as well as the education of youth. This call to civic role is in all the charters, a fact and purpose which so many pundits of today, e.g., Jamie Dimon, who see education on as job training, have overlooked (Lewis, DS 4.1, 12:55).

Educating engineers to be smart, to publish scientific articles like we faculty do, may not produce leaders (Krieger, DS 1, 00:00). In industry, the best people in research are not necessarily the best leaders (Briant, DS 1, 02:27). Leadership, though, is not something that can be taught like the calculus; students need to discover and develop this in relations with others; we need to provide them with the opportunity to learn about

social organization so that they can lead (Cheville, DS 1, 04:36). At WPI, the integrative projects give students that opportunity and some shine in this respect. But there was not a high correlation between grades and success on a project (Orr, DS 1, 03:37). Project based learning aside, it is no wonder that leadership receives so little attention and that engineers lack political power: Our teaching is all about means to ends, with little attention to who sets the ends or how ends are discovered, determined, or selected (Trilling, DO 2, 10:42).

While the rhetoric we contend with daily implies that training for a job is at odds with education for life via the liberal arts - it doesn't have to be that way. Students can have it all - preparation for a job and a liberal education. (Krieger, DS 4.2, 00:15) This is one way to see Liberal Studies in Engineering - as an attempt to accomplish both objectives, or at least as a first step in that direction. The intent is to mix the liberal arts and engineering in a way that achieves the aims of the liberal arts while attending to the ingredients of engineering thought and practice. We need to look to the long term, not restrict our purpose to life immediately after graduation

Our workshop participants stressed the importance of the liberal arts in the development of the whole person - promoting student's capabilities for analytical thinking; multiple framing of events and ideas; critical reflection; and practical reasoning. We need to help engineers to better reflect on their knowledge, their expertise and their identity and, most important, on their commitments (Downey, DS AP, 13:34) We ought not to think of education as transfer of knowledge, or simply knowledge for its own sake but as a process of transformation. Education is not only to change the world but we are changed. Don't confuse consumption of information with transformation of the individual (Kallenberg, DS 5.1, 05:31). In trying to create something new in our students, in our culture, we should not overlook the need for newness in ourselves (Boudreau, DS 1, 13:08).

Culture, Values, Mindset.

> In the face of women's attrition from engineering, the tried and true response is to propose yet another curricular reform. Without taking account of what is learned indirectly through initiation rituals and anticipatory socialization and its attendant impact on women's professional role confidence is to miss yet one more opportunity to achieve parity in a profession that has demonstrated remarkable resilience in maintaining the status quo[7].

Concern for the relatively low number of women who choose to study (and persist) in engineering was seen as a question of values - of the individual and of engineering culture.

We need to think about the language we use in discussing a question such as this (Adams, DS 2.1, 00:00). We should not cast the "problem" as one of "obstacles" to women who seek to become engineers. That reflects an engineering way of thinking; women may be excited about other things (Didier, DO 2, 02:57). One reason why women leave engineering is because they don't find it interesting (Silbey, DS 4.1, 09:23). Reference was made to a study done some twenty years ago with the support of one of the NSF coalitions that sifted through thousands of interviews to capture the reasons why women and minorities left engineering. Attrition is not the right word; women and minorities rejected engineering because they wanted to do something of value. It was a massive social protest (Jeremijenko, DS 2.1, 21:54). But we ought to distinguish minority groups from women; these are two different "problematique" (Didier, DO 2, 02:57)

7. Seron, C., Silbey, S., Cech, E., Rubineau, B. *Persistence is Cultural: Professional Socialization and the Reproduction of Gender;* work in progress.

When does initiation into a culture, the culture of engineering, begin? How far back do we have to go? Reference was made to an informal survey of some 300 college students in the liberal arts. Third grade seemed to be the level at which they were "turned off" from mathematics. The problem is that elementary school teachers are ill equipped to take an inarticulate question posed by a student and turn it into an articulate question (Pitt, DS 2.2, 02:12). Yet it was noted that girls choose a career path much later in life; they must free themselves of parental constraints. This contradicts the notion that we have to catch them early (Tobias, DS 2.1, 15:53). At Cal Poly, women students make the decision to enter engineering after a semester in college (Lehr, DS 2.1, 11:49).

Symptomatic of value differences is the way engineering faculty talk about the humanities courses their students are required to "take"[8]. These - a course in history, in english, in sociology - are "soft"; the core courses in his or her engineering major - the engineering mechanics, the thermodynamics, the electronics - are "hard". Engineering may be so perceived as "hard" but knowing that you can verify your solution to a problem actually makes it easier. (Haungs, DS 2.1, 00:27). Yet students avoid a history course that requires a lot of writing claiming "I really can't write". They start from the presumption that writing is easy for the liberal arts scholar - like it comes naturally. Students are surprised when told how hard it is to write; we need to get away from this "hard-easy" dichotomy" (McCants, DS 2.1, 02:45).

There are, for sure, distinct differences in the liberal arts and engineering cultures. One attributed "linear thinking" to the engineer, "associative thinking" to the liberal arts (Boudreau, DS 1, 13:08). One learns to be more "specific" when working with engineering students and their teachers in a problem-based curriculum; no hand-waving, generalizations, allowed (Lehr, DS 1, 09:42).

Students ought to come to understand the difference between the "practical arts" and the "liberal arts" - not with a hierarchy attached to them but just a clear-headed sense of what the differences are (McCants, DS 5.1, 11:52). This is one of the goals of liberal studies - to engage students in the "hard" problem solving and making of engineering while, within the same academic milieu, working on the hard problems of observing, interpreting and theorizing about social relations and organizations. We should help them to reflect on the experience and the broader context of problem-setting as well as engaging in that problem solving. Some saw this as requiring a "double consciousness" [9] (Boudreau, DS 5.2, 10:08). Another used the phrase "code switching" - the need to enable students to negotiate learning for engineering practice with learning how to do critical reflection on contemporary practice; STS is one avenue for the latter (Lehr, DS 5.1, 04:35).

We need to be open to, promote the discussion of values, of different value systems (Boudreau, DS 1, 13:08). At Lafayette College, students benefit from the contrast of different cultures' ways of addressing similar problems - the approaches to flood prevention in the US and in the Netherlands (Rossmann, DS 3., 16:3). It was reported that NSF is interested in supporting research on value systems and the formal and informal processes by which people become engineers. The solicitation (#15-539) notes that "processes of formation are holistic attending to how knowledge and person are related in one's life" (Riley, DS 3, 10:49). What are the values inherent, implicit, in the way we teach engineering, in particular, the engineering sciences (Downey, DS AP, 13:39).

8. Our language is deficient here: We need a better word, phrase than "take" in accord with our desire to move the student from out of the line of fire and into a more active position in the classroom.

9. Reference was made to Emerson and DuBois.

In a recent dissertation[10], research was done on engineering faculty involved with educational change projects motivated in part by the NAE report (phase I) "Engineer of 2020". All the faculty valued the report.s ideas about what engineering education should be but struggled with other "competing commitments". They felt their job was to cover well defined content and they were uncomfortable with student-centered approaches. In effect, they experienced an identity crisis: "If I go there, am I still doing engineering?" Other research supports how engineering faculty worry about looking incompetent when trying new teaching approaches or new content that wasn't a part of their education. They might include new ideas at the margins but claimed that others should take the lead in teaching this additional content. (Adams, DS 2.1, 19:54).

But, we were reminded, culture is not constant, an invariant. Contemporary engineering faculty's values and norms derived form Vannevar Bush report *Science, The Endless Frontier* (July 1945) in which basic research in science was claimed the driver of technological progress. Government support of science based research in engineering ought not to be taken as a given. In the past it was possible to be awarded tenure without ever writing a research proposal. Engineering research was not always considered a legitimate form of scholarship. (Pister, DS 2.2, 15:53) A historical perspective helps us understand the tension. When John R. Freeman was president of ASME, back in the late 19th century, the engineering curriculum was based in mathematics but the idea that the humanities were important was strong. Great emphasis was placed on teaching students how to write, to express themselves. Freeman was a member of the MIT corporation for 42 years but Vannevar Bush in an obituary[11] damns him with faint praise; Freeman wasn't scientific enough: "Without the full mathematical equipment available and necessary to engineers of the new generation, he could nevertheless arrive, as by constructive shorthand, at clear concepts and dependable results." (Jackson, DS 2.2, 06:49) Again the question arises: Just what, how much, math and science is truly prerequisite to doing engineering in the world?

Teachers, Students

Several participants noted the need for collaboration among faculty of different academic disciplines if teaching, mixing engineering with the liberal arts were to be done with integrity. They had themselves been there and valued the experience. No doubt that this takes work; it requires listening and thought beyond the bounds of one's scholarly domain. The development and installation of the *Liberal Arts and Engineering Studies* program at Cal Poly required two tries, the first a failure - a process fully described in a recent publication in Engineering Studies[12] (Haungs, DS 6.1, 11:02).

This need for openness extends to interaction and exchange with students. Listening to students and promoting open discussion may be sine qua non of the class room in the liberal arts - many in the Liberal Arts have taught in accord with the "flipped classroom" for years; in the main, they do not operate within the traditional lecture mode[13] (Lehr, DS 2.1, 11:49) - this is not the tradition, the norm, in engineering - except in

10. Siddiqui, J. (2014), Transformation of Engineering Education: Taking a Perspective for the Challenges of Change, PhD Dissertation: Purdue University.

11. Bush, V., *Biographical Memoir Of John Ripley Freeman 1855-1932,* NAS, Biographical Memoirs, vol. xvii, Eighth Memoir, 1935.

12. Gillette, D.D., Lowham, E., Haungs, M., *When the Hourly-Burly's Done, of Battles Lost and Won: How a Hybrid Program of Study Emerged from the Toil and Trouble of Stirring Liberal Arts into an Engineering Cauldron at a Public Polytechnic,* Engineering Studies, 2014 http://dx.doi.org/10.1080/19378629.2014.944186

a capstone design course. But even there, instrumental rationality, finding efficient and effective means to a given end, dominates. The uncertainties and ambiguities - none-the-less value questions that might surface with serious attention to a broader vision of context - are avoided or resolved through the machinery of focus group interviews or market survey. And in the engineering science course, only tried and true concepts, principles and methods are taught. No questioning of authority allowed. Problems assigned are normally well posed and admit of but a single answer.

This haughty status of engineering knowledge and technique is reflected in faculty attitudes toward their students: Faculty seem to say "if its good enough for me, its good enough for you; If I suffered, you suffer; look how successful I am". (Krieger, DS 2.1, 16:41).

To right matters, liberal studies will require the need for faculty to see themselves as a coach, a mentor rather than as a source and transmitter of knowledge and author of the textbook's solution manual (Bertoline, DS 2.1, 04:28) Faculty must be able to accept a student's awkward expression of misunderstanding, remake, and respond. Engineering students don't know how to deal with difficulty (Tobias, DS 2.1, 09:38).

We need to develop the student's confidence, to take "failure" - not getting the right answer to the problem - as an occasion for learning, reject the engineering mind set that sees nature rather than nurture as determining students ability to learn; it's important to build students' confidence; it's really a question of the student's maturity - how they manage (Haungs, DS 2.1, 00:27).

We have to give students the means "to go outside their comfort zone" and show them strategies for doing such. We want students to say "I find my mistakes interesting" (Tobias, DS 2.1, 09:38). And we should show students how we too are fallible; how we made mistakes; what was "hard" for us as learner. (Fortenberry, DS 2.1, 05:21). Showing how "mistakes" have been made by those upon whose shoulders we stand is one sure way of prompting open, reflective discussion as is the norm in the liberal arts but sorely lacking in the engineering classroom. There are many examples we can draw upon in the History of Science (and Engineering).

The Integrity of Disciplines

Would not the liberal arts faculty see our proposal at a threat? Would not including hard engineering content in a humanities course corrupt, diminish the purity of a historical study, a philosophical analysis, a literary critique? Will faculty see Liberal Studies in Engineering as helpful or as a threat? (Boudreau, DS 1, 13:08). Phrasing the question in a more constructive, positive way: What can Liberal Studies in Engineering offer the liberal arts? (Michelfelder, DS 5.2, 07:10)

Conversely, would not the piecemeal presentation of episodes of engineering theories oversimplify and fail to do justice to whole bodies of scientific knowledge upon which the so powerful instrumental methods applied in engineering practice rely for their veracity? (Heywood, DS 3, 17:46).

Faculty colleagues in engineering no doubt will view liberal studies in engineering at "engineering lite". Faculty of Harvard's AB in Engineering program are determined to avoid being labeled this way. (Lewis, Session 3). We need to respond to that pejorative. But we ought not be viewed as an engineering program heavy or lite; we intend to be grounded in the liberal arts (Bucciarelli, DS AP, 03:25) Think of what we are

13. Interestingly, little mention was made of MOOCs or to the online enhancement of residential courses. Many participants have already adapting the technology to advantage in their teaching. Apparently the topic did not measure up as worthy of debate.

about as making liberal arts courses "engineeirng rich" (Krieger, DS 3, 00:00). This is not about "engineering lite" but about making engineers capable of playing a larger role in the organization, the firm, the agency and in society. Current engineering education makes them incapable of taking on this role. Liberal Studies in Engineering is not a foolish idea. We have to figure out a way of doing this. (Krieger, DS AP, 08:40)

More constructively, we suggest that *Liberal Studies in Engineering* ought not to be judged according to the ways and norms of well established scholarly disciplines but viewed as a new domain for research as well as teaching. We suggest that moving faculty to stretch, reach outside their comfort zone can be the occasion for new ideas, fresh ways of seeing their worlds and building upon, but not constrained by, the solidity of tradition. Perhaps it might lead to new research projects; Cal Poly's Center for Expressive Technologies developed in this way out of an "...unofficial grassroots organization by passionate faculty in the Liberal Arts and Engineering Studies (LAES) Program" (Gillette, DS 1, 24:24) Everything we are talking about at this workshop is research. (Mili, DS 1, 10:06)

Constraints and Opportunities

The summaries of Session 6, *Transcending Silos....* point to the challenges of the task ahead. The priority given research by faculty and the centrality of disciplines has to be acknowledged. If we ask faculty to behave differently from what is valued in the disciplines, that is, integrating liberal studies and engineering the experiment may not work. (Thomas, Session 6).

We should recognize that the research university's engineering culture is shaped externally as well as internally. (Pister, DS 2.2, 15:53). So too in the EU, in particular in France, educational change including change in content, can be made for political reasons. (Didier, DO 2., 02:57) And note was made of how engineering practice has changed dramatically - change requiring educational reform beyond courses in ethics, team work and communication skills. Look at how Boeing designs and manufactures aircraft today: think of the responsibilities of the engineer in this day and age of logistics and manufacturing complexity. We need to be bold. There is an opportunity here. "We need Liberal Studies in Engineering" (Harris, DS AP, 10:49)

ABET is often viewed as a constraint on educational innovation. But is that justified? Were not the revision of criteria for accreditation that were promulgated in the nineties meant to stimulate needed change, e.g., serious attention to the social context of engineering work? ABET has changed. We should get ABET involved as a "cultural partner" (Orr, DS 1, 22:19). While they might be seen as an obstacle, we should work with ABET, invite them to help us change the culture (Pitt, DS 1., 21:29)

Recognizing the diversity of institutions of higher education in the US - and recall that my list of possible sites for liberal studies in engineering programs included community colleges, liberal arts colleges as well as universities - how do we work up designs for programs that respect this diversity yet still share in common the core idea - engineering content taught from the perspective of the humanities and social sciences? (Bradley, DS AP, 12:41)

This question prompted another: Are we aiming to establish small programs on the margins or do we have grander ambitions? Will we be satisfied with a set of modules, a course or two, a minor perhaps, a "boutique program" for producing a few Leonardos (read Renaissance student)? Or do we have grander ambitions, e.g., being bold, to solve a two culture problem? (Klein, DS AP, 06:33)

And do there not already exist programs doing what we intend to do? Indeed, Lafayette College, Smith, Dartmouth, Cal Poly and WPI can all rightfully claim that their engineering students receive a strong liberal arts education, stronger than is the norm, while pursuing an engineering degree. For example, every

student at Dartmouth, whether or not in engineering, has to earn a liberal arts degree (A.B.) along the way to the ABET accredited engineering degree which makes students in Dartmouth's a 5 year program (Helble, Session 3).

WPI has emphasized project based learning as a driver of education. (Orr, DS 1, 03:37) So too, Cal Poly. Like the increased attention and infusion of design into the engineering major, this "turn" to the project as vehicle for learning opens up the classroom to features not encountered in the traditional classroom - the ambiguity and uncertainty of task construction, the need to negotiate multiple perspectives, reflection on ends as well as means, while not shirking the need for sound, analytical thinking.

Of similar value is the engineering internship - not just to the student but to those of us urging reform that brings undergraduate engineering education more in line with engineering practice. Students return from time with industry and put pressure on faculty to change. (Pitt, DS 5.1., 07:14) Think too about the educational value of the intercollegiate projects where students from business as well as engineering - even from the liberal arts - work together in relatively small teams to design, build and test competitively a solar car, a solar house, steel bridge. They research and market, build and rebuild, and exalt in their productions when done. Probably the best engineering learning experience many, but not all, undergraduates will have and most of this carries no academic credit.

Think too of the "hacker spaces" which can be viewed as informal economies of making stuff. These provide a model of a way in which the liberal arts and engineering interact - critical making/critical thinking. (Jeremijenko, DS 4.2., 00:00) Do these informal "creative niches" support "critical making"; what value systems are inherent in this educational/entrepreneurial affair? (Kroes, DS 4.2, 09:50).

To actually establish a whole new undergraduate major or degree program is a tall order. Recognizing the obstacles to major reform of this sort, we have a two pronged attack - one aimed at establishing and sustaining a full program, the second focused on the design and development of modules like those developed at WPI (Krieger, DS 3, 00:00) These mix Chinese Studies with Civil Engineering - learning units which capture the core idea and can be put to use in the classroom without so disruptive an effect as the installation of a whole program (Rudolph, Session 3).

What's a module? What learning materials are included in a module? What about guidelines for instructors? And how will we measure student learning? How will we evaluate the effectiveness of a module? These are questions needing answers. (Downey, DS 3, 04:01) (Rudolph, DS 3, 04:33 for response). A module needs to be able to be implemented in a variety of contexts; it has to have an assessment component; Discipline-Based Education Research can serve as a source of many modules[14] (Bradley, DS 3, 09:31).

The need for faculty development was noted: This is a particularly hard nut to crack if, as we anticipate, the development of content and teaching will require the collaboration of scholars across engineering and the liberal arts. Purdue gives faculty release time, brings in new faculty earlier to prepare them for teaching across disciplines (Bertoline, DS 2.1, 01:50). At Cal Poly, informal meetings with a focus on funding proved motivational; getting individuals to sit in on others' classroom and making that the norm also helped bring faculty together. (Gillette, DS 1, 24:24).

How to motivate faculty in the first place? Would a perceived status difference between engineering faculty and their colleagues the other end of campus (and salary differential) work against collaboration? (Krieger,

14. *Discipline-Based Education Research: Understanding and Improving Learning in Undergraduate Science and Engineering* (2012).

DS 4.2, 15:00) Most who become scholars in the liberal arts are not driven by the possibility accumulating great wealth. Liberal arts education is not about making a living but about living. (Silbey, DS 4.2., 20:20).

We need to think about this: What is an engineer? (Orr, DS 5.2., 14:47)

Workshop Participants

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Kristin is an Associate Dean, Professor & Department Head, Humanities & Arts at WPI. A scholar of 19th century American literature, she collaborates with colleagues in engineering and the social sciences in developing interdisciplinary, role-playing simulations that model the engineering challenge of ensuring clean water to developing communities while providing a rich cultural context that attends to historical particulars while also teaching a variety of disciplinary approaches.

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David is an associate professor of physics & astronomy at Vassar College. His research focuses on physics pedagogy and architectural acoustics - his PhD is in Architectural Engineering -

and he has developed an acoustics course for non-majors. He was awarded an NSF CAREER Award in 2011 and is Vassar's faculty advisor to students pursuing an engineering degree under the college's dual-degree program in collaboration with Dartmouth.

Clyde Briant (Advisory Panel) clyde_briant@brown.edu

Clyde is Otis E. Randall University Professor and Professor of Engineering at Brown. From 2003-2006 he served of Dean of Engineering at Brown and from 2006-2013 as Vice President for Research. He, together with colleagues in the School of Engineering, are exploring how they might implement the core ideas of Liberal Studies in Engineering at Brown.

Terry Bristol bristol@isepp.org

Terry is the President and Executive Director of The Institute for Science, Engineering and Public Policy - a public, non-profit corporation affiliated with Portland State University dedicated to the development of local understanding of issues concerning science, technology and society. Born and raised in Portland, he received his undergraduate degree from the University of California at Berkeley (philosophy of science) and completed four years of graduate study in History and Philosophy of Science at the University of London in England.

Louis Bucciarelli (Co-PI) llbjr@mit.edu

Larry is a professor emeritus at MIT with a joint appointment in the School of Engineering and in the School of Humanities, Arts, and Social Sciences. He was one of the founders of Concourse, a transdisciplinary, collaboratively taught program for freshmen, and was a co-PI on the NSF funded ECSEL coalition of engineering schools formed to renovate engineering education via the integration of design throughout the curriculum.

Anders Buch (EU) buch@learning.aau.dk

Anders is an associate professor in Techno-Anthropology at Aalborg University, Copenhagen, Department for Learning and Philosophy. He is affiliated to the Center for Design, Innovation and Sustainable Transitions (DIST). He has published articles and books on knowledge, learning, education, and the professional development of engineers.

Javier Canavate (EU) francisco.javier.canavate@upc.edu

Javier is Dean, School of Engineering in Terrassa (EET), a school of the Technical University of Catalonia Barcelona Tech (UPC) Spain. He has worked as International coordinator of, and participated in, several European educational projects and has authored an official guide to the development and implementation of engineering programs

Alan Cheville alan.cheville@bucknell.edu

Alan holds the T. Jefferson Miers Chair as Professor of Electrical Engineering at Bucknell. He served two and a half years as a program director in engineering education at NSF. He has written about the complex interface between engineering education and the larger social, intellectual, and economic contexts in which it is embedded from a philosophical perspective.

Steen Hyldgaard Christensen (EU) steenhc@plann.aau.dk.

Steen is an adjunct associate professor, Department of Development and Planning, University of Aalborg, Denmark. He has served as initiator, coordinator, co-author and editor-in-chief of Academica: *Philosophy in Engineering, Engineering in Context,* of Springer*: Engineering,*

Development and Philosophy: American, Chinese, and European Perspective, of two volumes forthcoming: *International Perspectives on Engineering Education; Engineering Identities, Epistemologies and Values*, and authored, with Jamison and Botin, Morgan & Claypool: *The Hybrid Imagination – Science and Technology in Cultural Perspective*. Current research: academic drift in engineering education.

Alice Daer alice.daer@asu.edu

Alice is an assistant professor of English and a member of the graduate program in Rhetoric, Writing, and Literacies at ASU, Tempe, Arizona. Her research of digital literacies, popular and internet culture, (especially videogames) is grounded in both theoretical and empirical approaches to the study of how people write and learn to write - how users and designers "speak" to each other via selfies, hashtags, listicles, photobombs, GIFs, tweets, vaguebooks, reblogs, and pins.

Christelle Didier ***(EU)*** christelle.didier@univ-lille3.fr

Christelle has a BS in Electrochemistry Engineering, an MA in Education, and a PhD in Sociology (EHESS), Paris. She is Assistant Professor in Education Sciences, Charles de Gaulle University (Lille, France); has coauthored *Ethique industrielle* (De Boeck, 1998), authored *Les inge´nieurs et l'e´thique. Pour un regard sociologique* (Hermes, 2008) and *Penser l'éthique des ingénieurs* (PUF, 2008) Research areas: engineering ethics and values, including historical, cultural and gender perspective, engineering education and culture

Gary Downey downeyg@vt.edu

Gary is Alumni Distinguished Professor, Science and Technology Studies, Virginia Tech. An "ethnographic listener" doing engineering studies, he serves as President of the Society for Social Studies of Science (2013-2015). His most recent book is *Engineers for Korea* (Morgan & Claypool Publishers, 2014; with Kyonghee Han). As Editor of *Engineering Studies: Journal of the International Network for Engineering Studies*, he is overseeing the review and publication of our paper, *Liberal Studies in Engineering - a Design Plan.*

David Drew ***(Co-PI)*** David.Drew@cgu.edu

David holds the Joseph B. Platt Chair in the School of Educational Studies at the Claremont Graduate University. His teaching focuses on STEM education and quantitative research methods. He has authored nine books about a) the improvement of mathematics and science instruction at all levels of education, b) the development and evaluation of effective undergraduate programs, c) building strong university research programs, and d) health education.

Dan Flath flath@macalester.edu

Dan earned a BS and MS in Electrical Engineering at Southern Methodist University, then an MA and PhD in Mathematics from Harvard. He wrote an Introduction to Number Theory and co-authors textbooks on calculus (with the Calculus Consortium based at Harvard). He has advised three summer undergrad research teams on engineering inspired projects. He was the recipient of the 2014 Distinguished College or University Teacher of Mathematics Award from the Mathematical Association of America, North Central Section.

Norman Fortenbury ***(Advisory Panel)*** N.Fortenberry@asee.org

Norman is Executive Director of the American Society for Engineering Education. He was the founding director of the Center for the Advancement of Scholarship on Engineering Education

at the National Academy of Engineering - an organization which promotes research on teaching and learning and seeks to translate research results into improved educational practices in pre-college, collegiate, and work-based settings. He previously served as director of the Division of Undergraduate Education (DUE) at the National Science Foundation.

Ray Fouche rfouche@purdue.edu

Rayvon is Professor and Director of the American Studies Program at Purdue. His three books explore the multiple intersections and relationships between cultural representation, racial identification, and technological design.

David Gillette. ddgillet@calpoly.edu

David is a Professor of English and Director of the Liberal Arts and Engineering Studies Program at Cal Poly. He studies and teaches interactive media design, film production and technical communication. He is co-author of the recent article in Engineering Studies on hybrid engineering/arts curriculum design: "When the Hurly-Burly's Done, of Battles Lost and Won: How a Hybrid Program of Study Emerged from the Toil and Trouble of Stirring Liberal Arts into an Engineering Cauldron at a Public Polytechnic."

Domenico Grasso (Advisory Panel) dg@udel.edu

Domenico is Provost of the University of Delaware. Previously, he held senior leadership positions at the University of Vermont, where he was first, Dean of the College of Engineering and Mathematical Sciences and then subsequently Vice President for Research and Dean of the Graduate College. Prior to joining UVM, Dr. Grasso was Rosemary Bradford Hewlett Professor and Founding Director of the Picker Engineering Program at Smith College, the first engineering program at a women's college in the United States.

Andrew Guswa aguswa@smith.edu

Drew joined the faculty at Smith College to help launch the Picker Engineering Program – the first engineering program at an all-women's college. A civil and environmental engineer, Drew imparts to his students a deep understanding of technical principles along with an appreciation for the societal and ecological contexts of engineering design practice. He is the Director of Smith's new Center for the Environment, Ecological Design, and Sustainability, providing students with opportunities to integrate knowledge across disciplines in support of environmental decisions and action.

Wesley L. Harris (Advisory Panel) weslhar@mit.edu

Wes is the Charles Stark Draper Professor of Aeronautics & Astronautics at MIT where he has also served as Associate Provost for Faculty Equity and Head, Department of Aeronautics and Astronautics. In the 1990's, he was Associate Administrator for Aeronautics at NASA Headquarters and prior to that, Dean of the School of Engineering at the University of Connecticut.

Michael Haungs mhaungs@calpoly.edu

Michael is a Professor and Co-Director of Liberal Arts and Engineering Studies Program at California Polytechnic State University, San Luis Obispo (Cal Poly). He researches operating systems, distributed systems, game design and programming, and computer science education. Current efforts include incorporating project-based learning in computer science and multi-

disciplinary education, developing interactive entertainment applications and coursework, and mobile computing.

Barrett Hazeltine barrett_hazeltine@brown.edu

Barrett, a professor Emeritus of Engineering at Brown, has written papers on digital logic, technology transfer, and engineering education; a textbook on electronic circuit design and another on small-scale technologies. He has taught in countries in Africa and South East Asia; a field guide to appropriate technology is now in press. Recipient of an award for teaching for so many years in succession at Brown, they named the award after him.

Joseph J. Helble ***(Advisory Panel)*** Joseph.J.Helble@dartmouth.edu

Joseph is a professor of engineering and dean of Dartmouth's Thayer School of Engineering. Dartmouth is alone among American universities in requiring engineering students to earn a bachelor of arts degree before earning their ABET-accredited bachelor of engineering degree, typically in a fifth year. Helble is a 2014 co-recipient of NAE's Bernard Gordon Prize for innovation in engineering education, and is a member of New Hampshire Gov. Maggie Hassan's 2014 Task Force on Science, Technology, Engineering and Math (STEM) Education.

Robert H. Herrick rherrick@purdue.edu

Robert is the Robert A. Hoffer Distinguished Professor of Electrical Engineering Technology at Purdue. He has pioneered in the incorporation of more active learning opportunities into his electrical engineering technology course by leveraging instructional tools which promote student engagement and appeal to diverse learning styles.

John Heywood heywoodj@eircom.net

John is Professorial Fellow Emeritus of Trinity College, Dublin, and formerly Director of teacher education in the university. He has a background in radio engineering and space research and is a Fellow of ASEE and an SMIEEE. His book on *Engineering Education: Research and Development in Curriculum and Instruction* received the 2006 award for the outstanding research publication from the Division for the Professions of the American Educational Research Association. He is particularly interested in the design of trans-disciplinary courses.

Donald C. Jackson jacksond@lafayette.edu

Donald is the Cornielia F. Hugel Professor of History at Lafayette College. He studies and writes about the development of water resources and the history of dams focusing, in particular, on the cultural and political context of their design and construction.

Natalie Jeremijenko njeremijenko@gmail.com

Natalie is an Associate Professor in the Visual Art Department and affiliated with the Computer Science Dept and Environmental Studies program, NYU. With degrees in biochemistry, engineering, neuroscience and History and Philosophy of Science, she does environmental art - living, interactive, politically provocative projects impossible to describe in three sentences.

Sharon Jones joness@up.edu

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Sharon is the Dean of the Shiley School of Engineering at the University of Portland. A licensed civil engineer with degrees from Columbia University, the University of Florida, and

Carnegie Mellon University, she is interested in engineering pedagogy, promoting diversity in the engineering profession, and developing opportunities to bridge engineering and the liberal arts Her research focused on applying decision-making methods to evaluate sustainability policies - infrastructure, developing economies, and particular industrial sectors.

Brad Kallenberg bkallenberg1@udayton.edu

Brad is a Professor of Theology & Ethics at the University of Dayton (OH). His bachelor's degree is in science education (physics and chemistry); his graduate degrees are in Biblical Studies and Philosopihical Theology. He teaches a variety of ethics courses, including "Christian Ethics and Engineering" for both graduate and undergraduate students.

Jud King (Advisory Panel) cjking@berkeley.edu

Jud has been the director of the Center for Studies in Higher Education, University of California, Berkeley and professor emeritus of chemical and bio-molecular engineering. At the Center, his research focuses on systemic and institutional concerns as well as issues specific to engineering and technical disciplines. He has served in a variety of academic and administrative posts on the UC Berkeley campus and the system level. Most recently, he was Provost and Senior Vice President - Academic Affairs of the University of California system (1995-2004)

J. Douglass Klein kleind@union.edu

Doug is the Kenneth B. Sharpe Professor of Economics, and the Director of the Environmental Science, Policy and Engineering (ESPE) Programs at Union College. ESPE offers a major in either Environmental Science or Environmental Policy, and a minor in Environmental Engineering. ESPE is distinctive for a liberal arts college in that engineering faculty play a major role. Doug also helped create Union's annual Symposium on Engineering and Liberal Education.

Martin Krieger krieger@price.usc.edu

Martin is a professor at USC's Sol Price School of Public Policy. He has worked in the fields of urban planning, environmental policy, entrepreneurship, mathematical models, and the role of the humanities in social science. His nine published books describe how planning, design, and physics and mathematics are actually done. His most recent book is *The Scholar's Survival Manual.* Professor Krieger has been a fellow at the Center for Advanced Study in the Behavioral Sciences and at the National Humanities Center, is a Fellow of the American Physical Society, and has won three consecutive Mellon Mentoring Awards, for mentoring undergraduates, faculty, and graduate students. He is trained as a physicist.

Peter A. Kroes (EU) P.A.Kroes@tudelft.nl

Peter is a professor in the Philosophy of Technology at Delft, the Netherlands. He has an engineering degree in physics (1974) and wrote a PhD thesis on the notion of time in physical theories (University of Nijmegen, 1982). He teaches, mainly engineering students, courses in the philosophy of science and technology and the ethics of technology.

Jane Lehr jlehr@calpoly.edu

Jane is Chair of Women's & Gender Studies and Associate Professor in Ethnic Studies at California Polytechnic State University, San Luis Obispo. She is also Director of the Science, Technology & Society Minors Program and Faculty Director of the Louis Stokes Alliance for

Minority and Underrepresented Student Participation (LSAMP) in STEM Program. Her graduate training is in Science & Technology Studies and Women's Studies at Virginia Tech and her teaching and research focus on the complex relationships between gender, race, culture, science, technology, and education.

Harry Lewis lewis@seas.harvard.edu

Harry, Gordon McKay Professor of Computer Science at Harvard, has recently been appointed interim dean of the Harvard School of Engineering and Applied Sciences. He served as dean of Harvard College (1995-2003) and has throughout his years at Harvard, actively shaped undergraduate education and student life - as director of undergraduate studies in computer science, as member of the Faculty Council, the Educational Policy Committee, Admissions committee....etc.

Juan Lucena jlucena@mines.edu

Juan is Professor and Director of Humanitarian Engineering at the Colorado School of Mines. His undergraduate degrees are in Mechanical and in Aeronautical Engineering (RPI); his Ph.D in STS is from Virginia Tech. He studies how politics and culture shape engineering and engineers and constructively challenges engineering students and faculty to always ask 'what is engineering for'. He has led projects such as Building the Global Engineer; Enhancing Engineering Education through Humanitarian Ethics; Engineering and Social Justice. Currently, with Prof. Jessica Rolston, he is researching how low-income/first generation students bring their knowledge and experience into engineering problem solving.

Anne E. C. McCants amccants@mit.edu

Anne is a Margaret MacVicar Faculty Fellow and Professor of History at MIT with research and teaching interests in the economic and social history of the Middle Ages and Early Modern Europe, as well as in the application of social science research methods across the disciplines. At MIT Anne serves as the Director of the Concourse Program, a Freshmen Learning Community dedicated to exploring fundamental questions that lie at the intersections of science, social science, and humanistic inquiry

Diane Michelfelder michelfelder@macalester.edu

Diane, a professor of philosophy, former provost and dean of the faculty at Macalester College, teaches and researches 20th century European philosophy and the philosophy of technology. Her current work focuses on the ethical and social implications of emerging technologies, particularly the Internet. A past president of the Society for Philosophy and Technology, she was instrumental in forming fPET (the Forum for Philosophy, Engineering and Technology). Currently she is co-editor-in-chief of the journal *Techné: Research in Philosophy and Technology.*

Fatma Mili fmili@purdue.edu

Fatma, PhD Computer Science, Univ. Pierre et Marie Curie, Paris, is Associate Dean of Educational R&D in Purdue's College of Technology. She, along with Gary Bertoline, are leading an effort to create Purdue's first competency-based degree program - a "learn-by-doing degree that is integrated with the humanities".

Byron Newberry Byron_Newberry@Baylor.edu

Byron is a Professor of Mechanical Engineering at Baylor. His research interests include the philosophy o f engineering, including engineering ethics. He teaches engineering design as well as courses in social and ethical issues in engineering and sustainable engineering.

Dean Nieusma nieusma@rpi.edu

Dean, an Associate Professor of STS at RPI with a BS in Engineering (U. Mich.) and graduate degrees in STS (RPI), is particularly interested in engineering reform efforts that work at the intersection of technical and social dimensions of engineering, including reforms motivated by social justice concerns. He has developed courses and curricula that integrate social sciences with engineering within Rensselaer's signature interdisciplinary Programs in Design and Innovation (PDI) -which he directs.

Babatunde A. Ogunnaike ogunnaik@udel.edu

Babatunde is the William L. Friend Chaired Professor of Chemical and Biomolecular Engineering and Dean of Engineering at the University of Delaware. He has a bachelor's degree in chemical engineering from the University of Lagos in Nigeria, a master's degree in statistics and a doctorate in chemical engineering from the University of Wisconsin Madison. As recently appointed dean, he seeks to revitalize engineering education enabling faculty to build upon cross-disciplinary course opportunities, innovative technology for course delivery and student entrepreneurship programs.

John Orr orr@wpi.edu

John, a Professor of Electrical & Computer Engineering, is co-director of WPI's Liberal Arts & Engineering (unaccredited) degree program. He has served as head of the Electrical and Computer Engineering, Dean of Undergraduate Studies and Provost. His professional interests include engineering education - curriculum development at both the undergraduate and graduate levels as well as in assessment and accreditation activities.

Bryan E. Penprase bryan.penprase@yale-nus.edu.sg

Bryan is the Frank P. Brackett Professor of Astronomy at Pomona College, in Claremont, CA. During the academic year 2012-13, as an American Council on Education Fellow at Yale studying online education - including STEM - he helped design many of the common curriculum science courses for the new Yale-NUS College in Singapore. He has also served as the co-Director of the Liberal Arts Consortium for Online Learning and led in organizing conferences on the Future of Liberal Arts in India in Bangalore in 2013, and is organizing further conferences on global liberal arts and sciences in New Delhi in 2014 and in Singapore in 2015.

Karl S. Pister pister@ce.berkeley.edu

Karl, Dean and Roy W. Carlson Professor of Engineering Emeritus at UC Berkeley, is Chair Emeritus of the governing board of the California Council on Science and Technology. He was Vice President-Educational Outreach of the University of California and Chancellor Emeritus of the University of California, Santa Cruz. At UC Berkeley, he was Dean of the College of Engineering and was the first holder of the Roy W. Carlson Chair in Engineering. From 1991-1996 he served as Chancellor, UC Santa Cruz.

Joe Pitt jcpitt@vt.edu

Joe is a Professor of Philosophy at Virginia Tech. He researches the history and philosophy of science and technology focusing on the impact of technologies on scientific change. He is Founding Editor of the journal Perspectives on Science: Historical, Philosophical, Social, published by MIT Press, and former Editor-in-Chief of Techné: Research in Philosophy and Technology.

Ann Reimers ann.reimers@science.doe.gov

Ann has an undergraduate degree in Mechanical Engineering (Univ. of Penn), a Masters degree in the same field (Univ. Del.) and, after working as an engineering in the area of submarine acoustics, obtained a D. Sc in Electrical Engineering (George Washington Univ). More recently she has moved into teaching at the high school level. This year she is the Albert Einstein Fellow at the US Department of Energy in the Office of Science.

Jessica Smith Rolston jrolston@mines.edu

Jessica holds a PhD in anthropology from the University of Michigan and bachelor's degrees in International Studies, Anthropology and Latin American Studies from Macalester College. She is the Hennebach Assistant Professor of Energy Policy in Liberal Arts and International Studies at the Colorado School of Mines, where she conducts research on corporate social responsibility in extractive industries and on the knowledge of low income, first generation engineering students.

Jenn Stroud Rossmann rossmanj@lafayette.edu

Jenn is associate professor and department head, mechanical engineering, Lafayette College. She researches the fluid dynamics of blood in vessels affected by atherosclerosis and aneurysm, and the aerodynamics of sports projectiles. She has developed and taught courses from a socio-technical perspective for both engineers (e.g. 2014 ASEE paper), and non-engineers (as described in her Inside Higher Ed essay). She is also a published fiction writer

Jennifer Rudolph jrudolph@wpi.edu

Jennifer is an Associate Professor, Asian History & International Studies at WPI. She, with colleagues, created WPI's China program including a China track for students, adding Mandarin language and China content to Humanities and Social Science courses. Recognizing that global education at a STEM school requires multiple approaches, she, along with colleagues and students, has created modules for STEM courses utilizing case studies from China.

Susan Silbey ssilbey@mit.edu

Susan is the Leon and Anne Goldberg Professor of Humanities, Professor of Sociology and Anthropology, and Professor of Behavioral and Policy Sciences, Sloan School of Management. Her research focuses on management systems for containing risks, including ethical lapses, as well as environment, health and safety hazards. She has also written about engineering education "The dialectic between expert knowledge and professional discretion: accreditation, social control and the limits of instrumental logic" (2009), and "Professional role confidence and gendered persistence in engineering," *American Sociological Review* (2011).

Xiaofeng (Denver) Tang xut2@psu.edu

Denver is a Post-doctoral Fellow in engineering ethics at Penn State's Rock Ethics Institute. He received a Bachelor of Engineering degree from Tsinghua University, Beijing and recently completed his PhD in the Department of Science and Technology Studies at RPI doing a dissertation on the integration of engineering and liberal education. At Penn State, he is working with the Leonhard Center for Enhancement of Engineering Education to develop modules for teaching engineering ethics.

Scott Thomas scott.thomas@cgu.edu

Scott is professor and dean of the School of Educational Studies at Claremont Graduate University. He teaches courses in the areas of higher education policy, the sociology of higher education, and research methods. His research focuses on issues of student success and stratification of opportunity in higher education - on defining and understanding the impacts and costs of academic pathways to and through the undergraduate years. He is the editor in chief at the *Journal of Higher Education.*

Sheila Tobias sheilaT@sheilatobias.com

Sheila, with a M.Phil and master's in history (Columbia), is the author of *Overcoming Math Anxiety, They're not Dumb, They're Different, Breaking the Science Barrier*, and *Rethinking Science as a Career.* More recently she served as consultant to the Sloan Foundation for development and launching of the professional master's in science and mathematics degree.

Leon Trilling trilling@mit.edu

Leon is a professor of Aeronautics and Astronautics and STS, Emeritus at MIT. He founded the Integrated Studies Program at MIT. He is currently engaged in developing a middle school STEM program for Passamaquoddy 7th and 8th graders in collaboration with the Maine Indian Education Office and the Moosehorn National Wildlife Refuge staff.

James J. Winebrake jjwgpt@rit.edu

Jamie has a PhD in Energy Management and Policy (University of Pennsylvania), a B.S. in Physics (Lafayette College), and a M.S. in Technology and Policy (MIT). He serves as the dean of the College of Liberal Arts at RIT. One of his key initiatives is the integration of liberal arts and technology/engineering curricula at both the undergraduate and graduate levels.

Liberal Studies in Engineering - Broadening the Path to the Profession
Workshop Audio Play List

Friday, January 30, 2015 - Day 1

Introductory Remarks

Proctor Reid 05:02

Dr. Pramod Khargonekar14:26

Larry Bucciarelli08:13

David Drew 15:51

Discussion Opening_1 04:44

Bucciarelli; Krieger.

Discussion Opening_2 16:53

Lewis, 00:00; Orr, 01:24; Didier, 02:57; Drew, 05:52; Jones:, 07:17; Daer, 08:40; Trilling, 10:42; Pitt, 14:55; Pister, 16:21.

Discussion Opening_Gary Downey 12:31

Session 1 ***Lessons from the field*****:**

Moderator: Alan Cheville02:11

Kristin Boudreau, John Orr 18:42

David Gillette 14:37

Clyde Briant 12:33

Discussion Session_1 25:58

Krieger, 00:00:00; Briant, 00:02:27; Orr, 00:03:37; Cheville, 00:04:36; Lewis, 00:04:47; Ogunnaike, 00:06:15; Orr, 00:08:08; Krupczak, 00:09:00; Mili, 00:10:06; Briant, 00:11:36; Haungs, 00:12:02; Boudreau, 00:13:08; Bordoloi, 00:15:47; Penprase, 00:16:56; Gillette, 00:17:46; Pitt, 00:21:29; Orr, 00:22:19; Michelfelder, 00:23:10; Gillette, 00:24:24; Orr, 00:25:16.

Advisory Panel *Advisory Panel reflections*

Discussion Session_APPanel 20:11

Bristol, 00:00; Kroes, 00:43; Helble, 01:56; Kroes, 02:38; Harris, 02:46; Bucciarelli, 03:25; Grasso, 03:41; Heywood, 04:43; Klein, 06:33; Krieger, 08:40; Briant, 10:12; Harris, 10:49; Bradley, 12:41; Downey, 13:39.

Session 2 ***Challenges in Changing Eng.Ed:***

Moderator: Robin Adams 01:01

Sheila Tobias 17:14

Norman Fortenberry04:26

Gary Bertoline 08:11

Discussion Session_2.1 25:28

Adams, 00:00:00; Fortenberry, 00:00:18; Haungs, 00:00:27; Fortenberry, 00:02:08; McCants, 00:02:45; Bertoline, 00:04:28.50; Fortenberry, 00:05:21; Heywood, 00:05:55; Bertoline, 00:07:50; Tobias, 00:09:38; Fortenberry, 00:11:25; Lehr, 00:11:49; Fortenberry, 00:15:04; Tobias, 00:15:53; Krieger, 00:16:41; Bertoline, 00:18:47; Adams, 00:19:54.17; Jeremijenko, 00:21:54.39.

Discussion Session_2.2 22:39

Bristol, 00.00; Pitt, 00:02:12; Bertoline, 00:04:49; Jackson, 00:06:49; Briant, 00:09:49; Tobias, 00:10:47; Fortenberry, 00:11:50; Briant, 00:12:32; Orr, 00:12:47; Seigmund, 00:14:01; Pister, 00:15:53; Ogunnaike, 00:19:03; Riley; Bucciarelli, 00:21:17.

Session 3 ***Liberal Studies Program scenarios*****.**

Moderator: Harry Lewis 10:16

David Bradley 07:07

Joseph Helble 10:50

Jenn Stroud Rossmann10:45

Jennifer Rudolph10:43

Jamie Winebrake 10:01

Discussion Session_3 25:49

Krieger, 00:00:00; Rossmann, 00:01:23; Bristol, 00:02:15; Downey, 00:04:01; Rudolph, 00:04:33; Bradley?, 00:09:31; Winebrake, 00:10:09; Lewis, 00:10:32; Riley, 00:10:49; Kallenberg, 00:13:17; Rudolph, 00:13:51; Rossmann, 00:16:33; Heywood, 00:17:46; Winebrake, 00:21:15; Heywood, 00:22:14; Winebrake, 00:22:21; Guswa, 00:22:54; Rossmann, 00:23:25; Winebrake, 00:23:57.

Session 4 ***Liberal Studies, the View from Europe*****:**

Moderator: Steen Christensen (Denmark) 06:32

Javier Canavate (Spain)11:14

Christelle Didier (France)15:59

Peter Kroes (Netherlands)13:04

Discussion Session_4.1 22:20

Christensen, 00:00:00; Kroes, 00:00:09; Christensen - Kroes, 00:01:08; Christensen- Didier, 00:02:35; Christensen - Canavate, 00:03:54; Christensen, 00:04:33; Canavate, 00:05:59; Cheville, 00:06:49; Bristol, 00:07:22; Kroes, 00:09:10; Silbey, 00:09:23; Lewis, 00:12:55; Heywood, 00:14;10; Kroes, 00:18:45; Christensen, 00:19:20; Heywood, 00:21:01.

Discussion Session_4.2 21:59

Jeremijenko, 00:00:00; Canavate, 00:03:08; Kroes, 00:04:50; Didier, 00:05:58; Penprase, 00:10:13; Kroes, 00:11:53; Didier, 00:12:41; Krieger, 00:15:00; Kroes, 00:18:17; Silbey, 00:20:20.

Saturday, January 31, 2015 - Day 2

Session 5 ***Teaching Engineering: H&SS Perspective***

Introduction David Drew01:10

Moderator: Jane Lehr 14:40

Brad Kallenberg10:48

Anders Buch (Denmark)10:42

Anne McCants 13.11

Joe Pitt 09:06

Discussion Session_5.1 13:45

Bucciarelli, 00:00; Buch, 02:21; Lehr, 04:35; Kallenberg, 05:31; Pitt, 06:20; Bristol, 07:14; McCants, 11:52.

Discussion Session_5.2 15:32

Lehr, 00:00; Krieger, 00:14; McCants, 04:23; Adams, 05:05; Kallenberg, 06:33; Michelfelder, 07:10; Pitt, 08:42; Lehr, 09:42; Boudreau, 10:08; Jackson, 12:43; Orr, 14:47.

Session 6 : ***Transcending Silos***

Moderator: Bryan Penprase06:06

Jud King 09:25

Domenico Grasso10:06

Susan Silbey 15:43

Scott Thomas 08:20

Discussion Session_6.1 15:44

Penprase, 00:00; Krieger, 00:34; Trilling, 01:34; Haungs, 11:02; Silbey, 13:05; Daer, 13:23.

Discussion Session_6.2 16:33

Bristol, 00:00; King, 03:39; Penprase, 04:54; Bucciarelli, 05:18; Silbey, 06:32; Pister, 07:00; Boudreau, 10:02; Silbey, 11:55; Jones, 14:38.

Wrap-up Session: ***Next Steps for Liberal Studies in Engineering***

David Drew 08:10

Diane Michelfelder05:08

Ray Fouche 06:02

Larry Bucciarelli19:48

Funding Opportunities19:45

Gary Downey 08:35

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