

## **AC 2010-633: INTEGRATION OF ENGINEERING AND THE LIBERAL ARTS: A TWO-WAY STREET**

### **Cherrice Traver, Union College**

Cherrice Traver received her BS in Physics from the State University of New York at Albany in 1982 and her PhD in Electrical Engineering from the University of Virginia in 1988. She has been a faculty member at Union College in the Electrical and Computer Engineering department since 1986, and has been the Dean of Engineering since 2005. Recently Dr. Traver has been involved in initiatives at the interface of engineering and the liberal arts. She has led two national symposia on Engineering and Liberal Education at Union College and she was General Chair for the 2008 Frontiers in Education conference. Her teaching interests are in the Computer Engineering area including Digital Design, Embedded Systems, and VLSI. She has co-taught international project courses in Turkey and in Spain. Her research has been focused on timing issues in digital systems. She has directed local and national outreach programs, including Robot Camp and the P. O. Pistilli Scholarship.

### **J. Douglas Klein, Union College**

J. Douglass Klein is Dean of Interdisciplinary Studies and Special Programs and Professor of Economics at Union College. Klein joined the Union faculty in 1979, after earning a BA in Mathematics at Grinnell College, and a PhD in Economics at the University of Wisconsin, Madison. He has written on the economics of auctions, the measurement of economic efficiency, and the integration of engineering and liberal arts. As Dean, Klein oversees some fifteen interdisciplinary programs which draw faculty from across the campus. A subset of those programs seeks to integrate engineering and the liberal arts.

# **Integration of Engineering and the Liberal Arts: A Two-Way Street**

## **Abstract**

Many of the engineering “grand challenges” that have been identified for the future require a multi-disciplinary approach that integrates engineering and liberal arts disciplines. The focus of the work presented here is on preparing students from both areas for these challenges through the integration of undergraduate engineering and liberal arts curricula. The desire for this integration is motivated by the need for a more technically literate citizenship, work force, and political leadership, fostered by providing opportunities for students in technical and non-technical majors to work together.

We provide examples of curricular integration that do not require wholesale restructuring, which use methods that can be easily replicated, and which can be developed through the use of modest incentives utilizing existing courses and expertise. The specific methods of integration tested include guest lectures, course modules from different disciplinary perspectives, and pairing courses from different areas to address related topics. The assessment results, based on faculty and student surveys, suggest that these are sustainable models that can have a positive impact on faculty development and on student learning. When combined with other initiatives, such as sharing ideas and experiences with other institutions, it may be possible to shift academic culture toward a more integrated approach to education.

## **Introduction**

In June, 2008, speaking at the first Union College Symposium on Engineering and Liberal Education, Union’s President, Stephen Ainlay quoted a Union commencement address from 29 years earlier, June of 1979. The speaker then was C. P. Snow, whom Ainlay quotes as saying, “I am hopeful that given a bit of good fortune there will be a culture within perhaps two generations far more unified, better informed, and with a deeper sense of life.”<sup>1</sup>

We are now one generation past that commencement address, and 50 years past Snow’s Rede lecture on the “Two Cultures.”<sup>2</sup> Is bridging the cultures still important? And if so, what progress has been, or can be made to bridge the cultures? There are conflicting trends at work. On the one hand, the amount of knowledge in any field, technical or non-technical, is exploding at such a rate that to become expert demands greater and greater focus. On the other hand, addressing Snow’s lament and preparing students to work on complex, multi-faceted problems requires increased efforts to include more breadth in both engineering and liberal education.

This paper reports on one school’s pilot program to integrate engineering and liberal arts education, motivated by the need for a technically literate citizenship, work force, and political leadership, fostered by providing students in technical and non-technical programs opportunities to communicate with one another. Rather than take the approach of an institutional mandate for a “tech lit” requirement, we present models that are small-scale, portable, and that can be grown organically with the right incentives.

The three types of integration implemented were guest lectures, course modules, and paired courses. These interactions varied in duration and intensity, but all involved both faculty and students working together across disciplines to learn about the relationship between some aspect of engineering and technology and a related humanities, science, or social science topic. The paper will describe the process for launching the initiative, the incentives used, some specific examples, and a qualitative assessment of the resulting integration.

## Background

The world outside academia increasingly values people who can see and communicate beyond their own specialty. For example in discussing sources of innovation, Hargadon and Sutton observe that “the specialization and separation that help business units maintain focus also hamper communication.”<sup>3</sup> And looking backwards, Johansson has argued that the Italian Renaissance was fueled by the mixing of ideas created by east-west trade routes that passed through northern Italy.<sup>4</sup>

Those who push for integrative thinking are not advocating reducing the rigor of anyone’s education. Rather, they feel that by providing that education within a broader context, it becomes more useful and relevant. Achieving this relevance requires more a change in how education is conducted than what is taught. We hypothesize that creating occasional but periodic contact between engineering students and liberal arts students will improve their potential to share ideas and understand and value one another.

In *The Engineer of 2020*, the National Academy of Engineering makes the case for cross-disciplinary communication; engineers must be prepared to “engage multiple stakeholders,” and by symmetry the other stakeholders must also be prepared to engage engineers.

[G]ood engineering will require good **communication**. Engineering has always engaged multiple stakeholders – government, private industry, and the public. In the new century the parties that engineering ties together will increasingly involve interdisciplinary teams, globally diverse team members, public officials, and a global customer base. (NAE, p. 55; emphasis in original)<sup>5</sup>

The need for cross-disciplinary communication is not restricted to that between engineers and non-engineers. Carol Christ, President of Smith College, has noted that the rise of Area Studies in the humanities and social sciences has arisen out of the growing awareness that for people to understand a region, like Asia, Latin America, or (especially during the Cold War), Russia, “they needed the tools of multiple disciplines – history, political science, economics, sociology.”<sup>6</sup>

On a more dramatic note, authors ranging from Eric Drexler<sup>7</sup> to Bill Joy<sup>8</sup> to Braden Allenby<sup>9</sup> have noted the profound social and ethical challenges of a possible merging humanity with technology, and the need for dialog between technologists and humanists.

Engineering education, guided by ABET’s Criteria 2000,<sup>10</sup> increasingly stresses breadth in engineering education. The 1995 ABET Summary Report entitled “Vision for Change,” which

informed Criteria 2000, calls for “[a] new emphasis on teamwork, and a new awareness of economic, social, and environmental concerns will mark the leaders of the 21<sup>st</sup> century.”<sup>11</sup>

The Criteria 2000 learning outcomes are designed to produce, not simply better technically trained engineers, but graduates who can do engineering in context – the social, economic, cultural, environmental context that modern engineering demands. We believe that the opposite is also true: that to be prepared to lead in the 21<sup>st</sup> century, liberal arts graduates need to understand the technological context of modern society. To explore both improving engineering education and liberal education was the purpose of Union College’s 2007 proposal to the Andrew W. Mellon Foundation.

### **The Mellon Grant**

President Stephen C. Ainlay approached the Mellon Foundation with a request to increase the opportunities for engineering and liberal arts students to interact. The key part of the proposal reads as follows:

A significant part of our current strategic planning effort has been devoted to exploring ways of promoting curricular interactions between engineering and the liberal arts. We have developed courses and programs in intersectional areas such as nanotechnology (supported by the NSF), bioengineering (supported by HHMI) and digital arts (supported by an alumnus). We want to go farther and create many smaller intersections between engineering and the liberal arts through initiatives like "sister" courses (parallel courses on related topics taught by different faculty members) and through the interjection of cross-disciplinary modules into existing courses. We would like to create a culture in which it is routine for students to hear from experts from a different academic part of campus to give a different perspective on the course material.<sup>12</sup>

Note the focus on the integration of the engineering curriculum with the liberal arts curriculum rather than “technology for liberal arts” courses or “humanities for engineers.” The three categories of interactions proposed were: guest lectures, modules, and paired (“sister”) courses. The grant supported several methods to help faculty find one another, including social events, faculty meetings, as well as direct suggestions from the PIs. As noted in the assessment section below, some of the most successful matches were likely to have happened even in the absence of the grant because one or both of the faculty members involved were predisposed to make the kind of connections that the grant promoted.

Table 1 provides a summary of each of the kinds of interactions, and this is followed by descriptions of particular examples.

Type of Interaction	Description	Duration	Incentive
Guest Lectures	An engineering faculty member presenting one lecture in a liberal arts course, or vice versa.	65-100 minutes	\$200-\$250
Modules	One week of material, in the form of class or laboratory time.	3-6 hours	\$500
Paired Courses	Two courses taught in the same term, sharing three or more activities (lectures, labs, field trips, speakers, etc) in the same term.	At least 3 hours	\$1000

Table 1. Summary of Supported Interactions

Incentives were intended for the first offering of an interaction, and for lectures, supported up to two guests per course. Once lectures or modules were developed, the expectation was for them to continue to be offered. The hope is that once paired courses are developed, they will continue to be offered as paired in the future.

### Examples of interactions - Guest lecturers

- An engineering faculty member lectured in the History course, *Science, Medicine and Technology in Culture* on “Ancient and Modern Construction Technology.” The lecture provided an overview of construction methods, materials, styles of building, and design parameters. Materials covered are earth, stone, wood, brick, masonry, concrete, and steel. Methods included simple static framing to dynamic movable structures. Styles covered are simple huts all the way to earthquake- and wind-responsive structures.
- An engineering faculty member provided commentary to accompany a field trip between paired English and Environmental Studies courses (see below) along the Mohawk River and Schoharie Valley, providing commentary on engineering aspects of water flow control, water resources for New York City, and analysis of real (I-90 bridge collapse) and potential (Gilboa Dam) structural failures.
- A physics faculty member presented a lecture in a sophomore research seminar (a core research methods course), taught by an English professor, entitled, *Time: Changer of Seasons*. The course took a highly interdisciplinary look at the concept of time, and the physics professor presented a history of timekeeping, from ancient observatories to modern atomic fountain clocks that are accurate to 1s in 60 million years. The physics professor used the example of GPS systems to explain why such precise timekeeping had practical applications.

### Examples of interactions – Modules

- An engineering faculty member presented a module in *Introduction to Environmental Studies*, on “Water and Waste Water Engineering.” In this module, students are introduced to the history of water supply and waste water disposal, followed by discussion of the technology involved in drinking water treatment and distribution, and in waste water collection and treatment. Emphasis is placed on the engineer's role in the process.

- A chemistry faculty member presented a module in *Introduction to Environmental Studies* giving an overview of the various types of water pollution, from inorganic and organic pollutants to "bulk property" pollutants (such as temperature and salinity) and "micropollutants" (such as pharmaceuticals, personal care products, and other anthropogenic compounds present at low levels).
- An engineering faculty member contributed a module to a Latin course, *Reading Rome: Textual Approaches to the City*. The purpose of the course is twofold. First, for students to obtain greater proficiency in reading Latin, and second, for students to study the literary topography of ancient Rome. The course included three engineering lectures on infrastructure of ancient Rome, covering an introduction to Roman engineering (the arch, surveying, construction techniques, construction materials, and Roman roads); Roman aqueducts (planning, construction, operation and maintenance, and importance to the Roman Empire); and Roman Baths (construction and operation, plumbing, the inverted siphon and Roman sewers).

### Examples of interactions - Paired courses

- An Electrical and Computer Engineering course, *Engineering Acoustics*, and a Music course, *From Chant to Mozart*, paired to study Baroque instruments. A well known expert on harpsichords was invited to give a pair of lectures on the construction of harpsichords – one lecture from the point of view of the physics of the instrument and the other from the point of view of the artistic aspects of construction. This joint event connected the college with artisan instrument builders in the area and also led to new projects. By the next year, music history students studying the works of Bach visited the ECE department to see a clavichord (a Baroque period instrument) under construction by the EE students, as well as other interactive demos.
- A Biology course, *Neurobiology* and an Electrical and Computer Engineering course, *Discrete Systems*, paired to conduct neuroscience signal processing experiments. Students from the laboratory portions of the two classes were brought together to investigate the dynamics of a pair of well-known mechanoreceptors in crayfish, the stretch receptors. The biology students offered a basic anatomical and physiological understanding of the mechanoreceptor function, and had experience in the electrophysiological techniques required to record reliably from stretch-receptor axons. The engineering students offered knowledge and experience in digital filtering and analysis techniques such as spectral analysis (FFTs) and bandpass filtering. Students combined their knowledge and skills in a team approach to generating and analyzing real biological data.
- The already interdisciplinary course, *Frontiers of Nanotechnology and Nanomaterials* partnered with a Visual Arts course, *Photography II* produced a photo exhibition. The exhibition was produced by students and included electron microscope images representing applications in chemistry, biology, physics, mechanical and electrical engineering as well as artistic subject material related to those images. The engineering and science students learned about the physics of the microscope and experimental techniques needed to take careful images of micro and nanoscale samples. Visual arts students focused on the aesthetic aspects of imaging and juxtaposed their photographic works with electron microscope images. They also provided samples that presented

technical imaging challenges, which were subsequently solved by the Nanotechnology students in a follow-up laboratory.

- An Electrical and Computer Engineering course, *Engineering Acoustics* and a Music course, *Vocal Workshop* paired electrical engineering students studying signal processing and auditorium acoustics with students in the Vocal Chamber workshop. The two classes participated in a joint event in which the ECE students record the music students rehearsing in a dry classroom processed the signal so that it sounds like it was recorded in a large chapel. The ECE students also recorded the final concert in the chapel and challenged the music students to identify which was the synthetic signal. An earlier version of this collaboration was presented at the 2006 ASEE St. Lawrence Section conference.<sup>13</sup>
- Students in the English course, *American Literature in Historical Perspective: Beginnings to 1800*, partnered with students in *Introduction to Environmental Studies*, to consider the role landscape and environment play in major historical events and how that same landscape continues to shape the lives of individuals who live and work in the Schoharie valley. Shared activities include two lectures, one field trip, and a subsequent poster session with posters prepared by interdisciplinary teams drawn from the two classes. The field trip included commentary from an engineer with expertise in infrastructure.

The following section presents preliminary qualitative assessment results of the effect of the interactions on faculty and on students, and on the role of the incentives provided by the Mellon grant.

### **Assessment Plan and Results**

The assessment of the Mellon grant initiatives was conducted as part of the larger task of assessing the College's overall progress to integrate engineering and the liberal arts. Other initiatives that were assessed in the larger assessment include activities supported by other grants and relevant new courses, programs, majors, minors and clusters developed over the past five years.

Although there were other combinations of disciplines represented in the Mellon grant initiatives, the assessment data presented here is from modules, guest lectures and paired courses that include Engineering (and in one case Physics) and liberal arts (English, Art, Music, Environmental Studies) disciplines. As such the sample size is small and includes 10 faculty who were involved in five different integration experiences.

The goals of our assessment were to efficiently gather data and evaluate the origins and development of the integration ideas, the impact of the incentive funding, the impediments to developing these experiences, and student reactions to the integration of technical material into their courses. The assessment method was informal surveys sent as email to faculty who developed the guest lectures, modules and paired course experiences (as well as the faculty who incorporated these elements into their courses), and some focus group meetings with the students involved.

In the survey to faculty we asked about the origin of the ideas for the course lectures, modules, and paired courses. As part of the Mellon grant implementation, two “speed dating” sessions had been held to help faculty find compatible topics. Although these were not very well attended, we wanted to see if any of the ideas originated at these sessions. The assessment results showed that none of the guest lecture or module ideas came from the sessions, and most came from informal interactions or as part of the larger initiative to integrate and expand the introductory environmental studies course. Specifically:

- 2 ideas came from intro course development meetings
- 1 idea was suggested by the Mellon grant stewards
- 1 idea came from the course developer
- 1 idea grew out of other collaborations between faculty

As mentioned previously, the Mellon grant provided stipends as incentives to support faculty who made the effort to develop guest lectures, modules, or paired courses that integrate science and technology/engineering with the liberal arts. To determine the impact of the funding we asked faculty if they were aware of the availability of the stipends when they decided to develop the integrative experience, whether they would have implemented the experience without the incentive, and whether they plan to continue to offer the experience in the future. In all but one case, where the grant stewards suggested a paired course to the relevant faculty, the faculty were unaware of the incentives. And in all but that case, faculty stated that they would have developed the experience without the incentives. Although all faculty reported that they plan to continue to offer the lecture, module or paired course that they developed, when asked if they would do additional experiences without any incentives, only three gave a definitive “yes”, one said they would be less likely without incentives, and one indicated that his classes already incorporates science and technology into the learning experience.

Faculty were also asked about the impediments for creating integrative experiences between science/engineering/technology and liberal arts that they had to overcome. For those developing the modules and guest lectures, impediments included finding time (three responses), keeping the technical material sufficiently low level (two responses), and working out assignments and other logistics. For those incorporating the lectures and modules into their course, difficulties included the need to introduce some math concepts, and scheduling a time that works for both the course and the guest faculty member.

Since we are also interested in the sustainability of this endeavor, we asked faculty who had guest lectures and modules in their courses whether they could present the lecture or module (or a variant) themselves at some point. Responses to this question varied. One person felt that after seeing the module twice, they could teach it from their notes. Another felt they could do some parts, but not others. And another felt that they could teach a similar module, but that “guest speakers who are science/technology specialists are not just better qualified to answer questions, but their presence in the classroom is important for variety, depth, and scope of the course”.

Three focus group meetings were held with students, one with students who had a guest lecture, another with students who had an engineering module in their course, and one with students who participated in a paired course experience. This information was supplemented with email



answers to the questions posed at the focus group meeting from those students who did not attend. Questions were posed to discover whether students felt well-prepared for the material presented, whether they were held responsible for understanding the material through a graded assignment or exam, and their impressions of the perspective and contribution to the course topic that was added by the experience.

Students in the sophomore level “Time” course, taught by an English professor, had a guest lecture on atomic clocks from a Physics faculty member. Students agreed that they felt well-prepared for the material presented in the lecture, and that the lecture material was incorporated into quizzes and exams. The following comments from students were representative of the perspective they gained, the contributions they valued, and their overall impressions:

“I think the lecture was very helpful towards the overall concept of the class. It was good to have another view on the topic of time since it is both scientific and philosophical.”

“The thing that I remember the most about the lecture was the science that is behind global positioning systems. A GPS is something that I use almost once a week so it was interesting to find out how a small device in my car can find directions between two random places.”

“It made me realize how varied science could be and how many fields one could enter into with a science background.”

Students in the introduction to environmental studies course had a week long module (two lectures and a laboratory experience) on solar energy from a Mechanical Engineering faculty member. Students reported that they felt well-prepared for the module, which included a laboratory report assignment. The following comments from students were representative:

“[The module] added to my overall understanding of energy and the ability of solar panels and solar heating technologies to provide a good source of alternative energy for us.”

“It made me appreciate the value of understanding how to use our resources.”

“I thought that this was one of the better labs that we did over the course of the class. It was very interesting and informational, and helped me get a better understanding of what solar power is and what it can do and its true potential.”

For the paired course experience, students from a Photography II course worked with students in the Nanotechnology course on an art project that involved images taken by a Scanning Electron Microscope. The Photography II students were asked to describe their experience with the SEM as an artistic tool. The following quotes capture their assessment:

"A great part of art is being able to explore new ideas. This allows us to see entirely new things that you couldn't see otherwise, and to see them the way that scientists and engineers do."

"We got some insight into how engineers do things. We prepared the samples ourselves with a guided hand."

"As a freshman (art major), going into the science labs was a new experience. We got insights into what engineers do. I never knew we could take pictures of something so small."

"It was great. I felt like I got to make art in a way that very few people have. It was a unique experience."

The results of these assessments suggest that the faculty who were involved in the integration experiences had an intrinsic interest in doing it, and the grant incentive was a secondary incentive. The integration experiences in the introduction to environmental science course (of which there are several others that were not described here) have been a successful initiative to offer more sections of the course and integrate science, policy and engineering topics. It is encouraging that faculty found these experiences rewarding enough to continue to offer them in the future, and some envisioned developing more in the future, without incentives. The impediments did not seem serious, and faculty spoke positively about the experiences. The students did not complain about lacking the background to understand the technical material and in all cases the students were held accountable for the material presented in the lecture, module, or paired course experience. Comments indicated that many students were able to articulate the contribution of the additional perspective provided by the experience.

## **Future Work**

The underlying strategy of our approach to integrate engineering and the liberal arts through the types of experiences described in the previous section is to develop strong teaching relationships between faculty of different disciplines. We find that many of the experiences developed because of pre-existing collegial relationships such as working together on committees or other projects. Moving these relationships into the classroom helps to foster increased communication about both content and pedagogies, and can lead to a better understanding and appreciation for another discipline. If enough faculty become involved with the experiences, it can move the culture of the institution toward a more interdisciplinary approach to education.

The assessment results suggest that these experiences are intrinsically rewarding to faculty, but since they do require additional effort to implement, it is important that they also feel that the institution values their efforts. While the purpose of the Mellon grant and the incentives was to make that clear for these cases, the challenge ahead is to make sure that the institutional message about the value of these experiences is sustained. Some ideas for doing this include publicizing a list of cross-disciplinary teaching, holding a speaker series for faculty to talk about their experiences, and featuring articles about these experiences in official publications. Another proposal is to provide a budget to continue the incentives for new module development, particularly for the required sophomore research seminar in the general education curriculum.

Other types of initiatives to integrate engineering/technology and the liberal arts include the development of ten new interdisciplinary programs (both majors and minors) that include

engineering and computer science, interdisciplinary international experiences (Alternative Energy in New Zealand, GIS Mapping in Spain, Water Resources in Brazil, etc), team-taught courses (Nanotechnology and Nanomaterials, Introduction to Bioengineering, Entrepreneurship<sup>14</sup>, etc.), interdisciplinary computer science courses, interdisciplinary “clusters” (groups of courses required in general education program), and increased participation of engineering and computer science faculty in the core introductory general education courses.

As we work on these initiatives, it has been very valuable to interact with colleagues at other institutions who have similar goals. We have initiated an annual symposium that brings together faculty and administrators from these institutions, as well as scholars who have an interest in the intersection of engineering/technology and the liberal arts.

To assess our overall success in achieving a significant level of integration of engineering/technology and liberal arts at Union a set of metrics has been proposed. We have tracked data on the development of relevant new courses, programs, majors, minors and clusters and interdisciplinary exchanges among faculty, enrollments in these courses and programs, and the number and percentage of liberal arts students who take courses taught by engineering or computer science faculty. As we analyze this data along with available resources, we will be developing more specific goals that correspond to these metrics. Organizing and systematizing measures of student learning outcomes related to our integration goals will be the next assessment challenge.

## Conclusion

This paper has presented the rationale, goals, examples and preliminary assessment results for cross-disciplinary lectures, modules, and paired courses designed to link the undergraduate engineering and liberal arts curricula. These links support Union’s agenda for the broader integration of engineering and liberal education. We see this as a two-way street. We want to offer students in the liberal arts a contextual understanding of how technology relates to their discipline, an appreciation for science and technology, and experience communicating with those from other disciplines. Similarly we want to give students majoring in technical fields experience applying their skills to problems in other areas, and practice utilizing some of the ABET 2000 objectives in working with less-technical partners. The curricular examples developed through this project have modeled the kind of interactive behaviors that we think both engineering and liberal arts graduates will need. Continued assessment efforts will help us to monitor further progress. And Union will continue to seek and share lessons learned and best practices with peer institutions beyond this grant in order to further bridge the cultural divide between humanists, social scientists, scientists and engineers to ultimately realize our mutually beneficial educational goals.

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