AC 2010-1688: TEACHING TO ABET'S CRITERION 3(I) LIFELONG LEARNING OUTCOME: LESSONS ON INNOVATION FROM CREATIVE COMMUNITIES

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**Teaching to ABET's 3(i) Lifelong Learning Outcome:
Lessons on Innovation from Creative Communities**

“If you are lucky enough to have lived in Paris as a young man, then wherever you go for the rest of your life, it stays with you, for Paris is a moveable feast.”

~ Ernest Hemingway

In his commencement address to Stanford University's graduating class of 2005, Apple co-founder Steve Jobs recalled how, after dropping out of Reed College in his freshman year, he stuck around campus and experienced what can arguably be described as one of the most fortuitous learning experiences in the history of the world [1]:

Reed College at that time offered perhaps the best calligraphy instruction in the country. Throughout the campus every poster, every label on every drawer, was beautifully hand calligraphed. Because I had dropped out and didn't have to take the normal classes, I decided to take a calligraphy class to learn how to do this. I learned about serif and sans serif typefaces, about varying the amount of space between different letter combinations, about what makes great typography great. It was beautiful, historical, artistically subtle in a way that science can't capture, and I found it fascinating.

None of this had even a hope of any practical application in my life. But ten years later, when we were designing the first Macintosh computer, it all came back to me. And we designed it all into the Mac. It was the first computer with beautiful typography. If I had never dropped in on that single course in college, the Mac would have never had multiple typefaces or proportionally spaced fonts. And since Windows just copied the Mac, it's likely that no personal computer would have them.

No formal curriculum could have prepared Jobs for his innovative achievement as well as the serendipitous, intuitive, and self-directed pursuit of his own creative learning interests. Reed College is a progressive liberal arts school known for encouraging students to explore their individual intellectual interests—yet in his Stanford address, Jobs emphasized several times that he would *not* have taken the calligraphy class if he hadn't dropped out:

The minute I dropped out I could stop taking the required classes that didn't interest me, and begin dropping in on the ones that looked interesting. . . . And much of what I stumbled into by following my curiosity and intuition turned out to be priceless later on. . . .

Because I had dropped out and didn't have to take the normal classes, I decided to take a calligraphy class to learn how to do this. . . .

If I had never dropped out, I would have never dropped in on this calligraphy class, and personal computers might not have the wonderful typography that they do.

At the time Jobs entered Reed College as a freshman in 1972, the “computer science” degree offered by American universities had been in existence for only ten years [2]. Programming meant using a keypunch, carrying decks of punch cards in a shoe box to the card reader, and waiting endlessly for printouts to return from the mainframe. What are the chances that a program director in 1972 could have anticipated the potential for desktop publishing and designed a curriculum pointing toward such future innovation, especially a curriculum that incorporated a course like calligraphy?

More to the point of issues faced by engineering educators today, if an outcomes-assessment environment similar to today’s ABET’s engineering criteria had existed in 1972, would an advisor have encouraged a computer science major to take that calligraphy class he was interested in? (As a first-semester freshman, Steve Jobs was not a computer science major, by the way.) We should hope so, but as engineering programs are under pressure to demonstrate that their students have knowledge of contemporary issues, have an understanding of professional and ethical responsibility, have an ability to work within political/economic/social constraints, etc., the question that needs to be answered is: Where does calligraphy fit into ABET’s Criterion 3(a-k) outcomes?

Jobs ended his story by reiterating:

Again, you can’t connect the dots looking forward; you can only connect them looking backwards. So you have to trust that the dots will somehow connect in your future. You have to trust in something—your gut, destiny, life, karma, whatever. This approach has never let me down, and it has made all the difference in my life.

It seems unlikely that any formal curriculum could have prepared Jobs for his innovative achievement as did the serendipitous and intuitive (or even “karmic”?) self-directed pursuit of his own creative learning interests. That is why ABET Criterion 3(i), which calls for “a recognition of the need for, and an ability to engage in life-long learning” presents the Liberal Education Division with an intriguing challenge. It seems to be the one outcome that studying calligraphy could satisfy.

If “lifelong learning” were just a new term for “continuing education”—achieving certification by moving through a formally structured curriculum and developing specialized expertise via advanced degrees, certificate programs, and other defined training pathways—then “lifelong learning” would be merely more of the same, for the rest of one’s life.

However, the concept of lifelong learning is being redefined in terms of innovation, creativity, and knowledge transfer—especially as described in the economic policies of the European Union and in books like *A Whole New Mind*, by Daniel H. Pink, *Strategic*

Intuition, by William Duggan, *The Rise of the Creative Class*, by Richard Florida, and *Creativity*, by Mihaly Csikszentmihalyi. As the world becomes more interconnected and the various engineering disciplines require more knowledge of other fields, the need also increases for engineers to self-direct a path of lifelong learning *outside* the channels of formalized education—and to do so in way that contributes to a culture of creative innovation in their companies, their industries, and their societies.

Before EC 2000, engineering students were required by ABET to take the equivalent of one full term of liberal arts courses, the equivalent of 15 to 18 hours. That minimal requirement led to what has been described as “the ‘Chinese menu’ approach currently used by most schools” [3]. Today, however, that elective system appears to be disappearing. “Cafeteria” style learning conjures up images of students consuming a junk-food diet at a time when it is more important than ever for them to receive proper educational nutrition. As the need to assess educational outcomes leads to rubrics, and as rubrics in turn lead to curricula and course assignments that can be neatly measured, the higher education experience begins to resemble something less like a cafeteria than an assembly line.

It is also ironic that as higher education takes on the trappings of business (with documentation of “manufacturing” processes and quality-managed standardization of the “product”—i.e., graduates), at the same time businesses in creative industries (and even progressive companies within old-economy industries) are gravitating toward the unfettered practices long associated with ivory-tower academia in order to generate the innovative ideas needed for success in today’s global economy.

This paper begins, then, with the premise that meeting ABET’s Criterion 3(i) outcome requires more than simply graduating students who recognize the need to continue building up their qualifications via coursework, certificates, or degrees. The kind of lifelong learning that leads to innovation is a complex exercise in intellectual curiosity—and one that is far less formalized than most of our students’ educational experiences have prepared them to undertake.

The question is: How can formal education prepare students to learn outside of the classroom? Restated in terms more specific to us, how can teachers teach students to learn without teachers?

One answer can be found by examining the nature and practices of creative communities. Why? Creative communities provide a synergistic environment that encourages ongoing, informal (non-certified) learning experiences out of which innovation emerges predictably and organically. This conference paper examines several creative communities in a variety of fields, both historical and present-day, to learn what they can teach us about self-directed, lifelong learning. The specific communities discussed within this paper include the following:

1. Bell Laboratories, Murray Hill, New Jersey
2. Silicon Valley

3. Paris, France (the Impressionists and Hemingway's crowd)
4. Florence, Italy (during the Renaissance)
5. Pixar Animation Studios
6. Paducah, Kentucky (artist relocation program)

Several key principles associated with learning outside of formal education structures can be drawn from these creative communities, and although the practicalities of incorporating them into college classrooms may be difficult, implementation of these principles could help students develop the lifelong learning capacities necessary to meet the challenges facing 21st-century engineers.

Lesson #1 – A creative community needs a playground

The title of a 2001 article published in *IEEE Transactions on Electron Devices* pretty much sums up this principle: “Out to Murray Hill to Play: an Early History of Transistors.” [4] The article title is itself a pun, a “play” on words: the author's name is James Early. He says:

The early days of transistors began wonderfully, built mightily, and became the foundation for a major industry. They also paid our wages, and were great fun. The view of our occupation held by many of us is reflected in the words of my wife, Mary Agnes Early, circa 1956: “You go to Murray Hill to play while I take care of the house and the children.” Early in my work at Bell Labs, I grasped Bell's personnel strategy, which was to hire the ablest persons they could find having suitable background, and subsequently offer them a wide range of problems to attack. In his book “The Gifted Child,” Paul Witty has expressed that “Gifted children organize their play in complex patterns leading to remote goals.” The same is true if you replace “gifted children” by “research and development people,” and “play” by “work.”

Steven Chu, 1997 Nobel Laureate in Physics and currently the U.S. Secretary of Energy, describes a similar atmosphere at Bell Labs when he worked there during the 1970s and '80s [5]:

When most people think of industrial labs they think of, “Oh, you're making better widgets. You're making something that's going to be good for the phone system.” Now, ultimately, that's true. But at Bell Labs in that time—this is in 1978—allowed a small fraction of us—fifty, sixty, eighty—to do whatever we wanted; really to do whatever we wanted.

So I joined Bell Laboratories. My department head said, “Steve, you can do whatever you want. It doesn't even have to be physics. All we ask is that you don't go to a high-energy accelerator and do high-energy physics, because that would be hard on the stockholders.” (My thesis project, and when I was working as a post-doc, addressed a high-energy physics problem.) He said, “And by the way, don't do anything immediately. Spend six months. Talk to the people

around the labs, and just keep an open mind.” This was a devastating experience for me, because of the freedom to do whatever you want and being told, “Don’t do what you think you want to do now, but explore.” So I spent some time exploring and thinking. And there, I really felt pressure, because he would say, “We expect great things out of you.” I didn’t want to hear that. It’s much nicer to have a little problem to work on; it’s very cozy.

But it did have a real influence on me, because it got me in that mode of going and talking to people outside of my field. When I finally started doing things at Bell Laboratories . . . and I started, first, in an area that was in condensed matter physics that I knew nothing about, but using techniques in my old field, atomic physics and laser physics. But it got me into the mode of, “I’ve got this crazy idea.” I’d go to some colleague in Bell Laboratories and say, “How does this sound?” And they would tell me, “No, this is the stupidest thing I’ve heard,” or “Yeah, maybe you have something there.” It set the tone for what I’ve done for the rest of my life—collaborating with people, especially outside my local expertise. It was a wonderful experience.

I also should say, in the years I was there, ’78 to ’87—there was an economic slump in the mid-seventies; Bell Labs just started hiring people—and there were a group of us, maybe a few dozen, two or three dozen, and we all were young, energetic, bright-eyed, bushy-tailed. We were all being put in this position: “Do something important. Here are the resources of American Telephone and Telegraph System. We expect you to do something wonderful.” We were there at night. We were there on the weekends. We knew what each other’s cars looked like, so we knew who was in there, let’s say, on a Saturday or Sunday. We would party together. [Looking back,] I think either five or six of us [later] got Nobel Prizes. Over a dozen are in the National Academy of Sciences. It’s like this: we all were growing up together. And we had these really wonderful senior scientists there as well.

It was a remarkable period of time. Everything was exciting, and something would come along that was not in my field, and I would say, “Wow, this is really interesting.” We’d go in, we’d discuss it. People would jump fields, or jump areas. There was this feeling of the excitement of the science, that even though we were doing *this*, it was all right to move and do *that*. You wouldn’t be considered a failure because you gave up this, because something else even more exciting came along, either from your own laboratory or from a colleague’s lab, or from the outside world.

So freedom in the best sense, but in an environment where it could lead to new levels of understanding.

A positively electric atmosphere. You’d go in the lunchrooms and over lunch . . . everybody went there around noontime. You’d sit in these big round tables and, “Okay, what’s new?” People would leave; other people would come. You would

be sitting there chatting, socializing, but talking a lot about science. A lot of ideas were invented on those lunchroom tables. And so there, again, it was something where there was this real community.

It was pretty magical. People who are close to science and especially in the areas that Bell Labs was touching knew that there was something magical going on at the time. [?]

It is remarkable how frequently the concept of “play” emerges in descriptions of work in creative communities. In *A Moveable Feast*, Ernest Hemingway recalls ending his work days with an effortless shift into evenings of socializing with the many other writers, artists, and intellectuals living in 1920s Paris [6]. In Paducah, Kentucky, the city’s Artist Relocation Program that draws artists from around the country to resettle its historic riverfront district, an ancillary development has been the accompanying rise in galleries, coffee shops, and restaurants to support both tourism and the artists’ own desire to mingle [7]. A new book on Pixar Animation Studios, published in November 2009, is titled *Innovate the Pixar Way: Business Lessons from the World’s Most Creative Corporate Playground*.

Lesson #2 – A creative community needs a critical mass

In 2003 Milwaukee School of Engineering celebrated its 100th birthday. That same year, two other Milwaukee institutions also celebrated hundred-year anniversaries: Allen-Bradley (now Rockwell Automation) and Harley-Davidson. The year 1903 must have been an exciting time for engineering and technology—and not just in Milwaukee. In 1903 the Wright Brothers also made their historic powered flight, and Henry Ford founded the Ford Motor Company in Detroit.

At the same time, Dayton, Ohio, claimed to have more patents per capita than any other city in the United States [8]. Partly that statistic was skewed by the presence of the National Cash Register Corp., founded in 1884, a company that currently holds around 2,000 active patents [9]. However, during the early 1900s Dayton was also home to the Wright Brothers (with a mere seven patents) and Charles F. Kettering, who had over 300 patent applications and 140 patents to his name [10], [11], [12].

These bursts of innovation within three Great-Lakes-bordering states as the twentieth century began provide an example of “clustering,” a phenomenon described by Richard Florida in his widely cited book *The Rise of the Creative Class* [13]. History shows that creative people tend to cluster and that their own creativity flourishes in the presence of other creative people, even when the types of work everyone is doing have little (or nothing) directly in common.

Ernest Hemingway’s Paris of the 1920s, as portrayed in *A Moveable Feast*, was also a place with such a cluster [6]. Although individual artists and writers worked alone or in cafés, they all knew each other, met to drink or have meals together, and saw each other

frequently at places like Shakespeare and Company, the bookstore famous for its salon-like function.

Lesson #3 – A creative community needs patrons and produces value in return

The Renaissance period (roughly the fourteenth through the seventeenth centuries) had its beginnings in Florence, Italy, and during this period, the arts and sciences flourished in that city. Many possible reasons have been advanced to explain why Italy, and in particular why Florence, should have been the center of this tremendous and sustained explosion of creativity, but what seems particularly intriguing is the symbiotic connection that existed between patrons and creatives.

Florence was a center of banking and commerce, where men like Lorenzo de' Medici established a system of arts patronage that allowed them to display their power and wealth through the creative output of artists like Da Vinci, Botticelli, and Michelangelo. Historians have long debated the chicken-or-egg nature of Renaissance Florence: did the culture of the place (arts patronage) arise because there was such an incredible amount of talent in that one place, at that one time, or did the genius of these great men emerge as a result of the cultural conditions inherent in a city where so much wealth was being invested in creative output. That conundrum probably has no answer, but the primary lesson here is that a correlation exists. A city like Florence arises because of the confluence of talent and money.

Similarly, Silicon Valley originated from Stanford University's decision to create an industrial park on part of its land through long-term leases to high-tech companies—a mutually beneficial arrangement for both the university and the companies and a model for similar developments since then (for example, the Research Triangle Park region in North Carolina). As creative talent gravitated toward the area, so did venture capitalists. In fact, the emergence of the venture capital industry in the second half of the twentieth century is closely tied to the history of Silicon Valley. As with Florence, it is hard to say whether the money has followed the talent or the talent has followed the money—but it is clear that creativity and money have a symbiotic relationship.

In Paducah, Kentucky, on the banks of the Ohio River, a decaying and largely abandoned waterfront neighborhood of century-old buildings gained new life when the city established its “Artist Relocation Program” in August 2000 [7]. This award-winning program has become a national model for other cities hoping to revitalize their economies by attracting artists and developing “hip” centers for creative rebirth. The model is similar to Silicon Valley and Florence in that success was the result of focused cooperation between government, financiers, and artists. Implementation of new city ordinances limited the ability of landlords to carve up properties into multi-unit dwellings that were not up to code, making those properties less attractive rental investments and therefore more available for purchase by artists. Cooperation from the Paducah Bank allowed for artists to get 100% financing with low-cost loans [14], [15], [16].

Creative communities require both talented “creatives” and discerning patrons/venture capitalists committed to investing in their work.

Lesson #4 – A creative community needs a locus

The locus (or loci) of a creative community can be a mentor, a maven, a chaperone, or what writer Malcolm Gladwell calls a “connector” [17]. At Bell Labs, older scientists acted as mentors to the younger scientists. In Hemingway’s Paris, Gertrude Stein served as a maven, an expert Hemingway admired, and Sylvia Beach, owner of the famed Shakespeare and Company bookstore, served as a “connector,” who brought together artists and writers who lived in the city.

At Pixar, the uneasy corporate marriage with Disney as Pixar was poised to begin production of its first feature-length film, *Toy Story*, brought with it some new challenges to the company’s culture. Disney was uncomfortable with leaving the talented but inexperienced Pixar crew in charge of such an important project, so they assigned Hollywood veteran Bonnie Arnold, who had co-produced big films like *Dances with Wolves*, to supervise production of *Toy Story*. The Pixar culture was very ‘60s-like relaxed, and Arnold’s hard-charging, practical nature clashed. When she installed a loudspeaker intercom system to announce meetings, she nearly had a revolt on her hands. But she worked hard and got things done, eventually earning both respect and affection from the Pixar staff. The staff did its own work, but they needed Arnold’s “chaperone” style to manage their first really large project. [18]

In Paducah, Kentucky, the Artists Relocation Program owed much of its success to local artist Mark Barone. When he witnessed a drug deal one Saturday morning on the street corner outside his house, Barone nearly single-handedly transformed his neighborhood into a center of historic preservation and the arts. Working with the mayor, he was able to change city ordinances to discourage and establish the incentives initiative that drew artists to the Lower Town district of the Ohio River city. Barone personally met with many of the artists who responded to the ads for the program placed in national publications, showing them around the city, helping them find a property to buy, securing bank support for their loans, and guiding them through the process of resettlement [14].

Lesson #5 – A creative community produces synergy and cross-pollination

The French Impressionists were friends, artists bound together through their rejection by and of the artistic establishment. Although other artists of the day (mid to late 1800s) may have used similar themes and styles, the Impressionists developed a unique technique that captured light and created a way for viewers to see the world anew through the “impression” of form and light. Intensely interested in each other’s work, these painters learned from each other and were inspired to attempt ever more ambitious work of their own.

A few decades later, author Ernest Hemingway learned some of his most important lessons about writing from the French impressionist painter Cezanne. In *A Moveable*

Feast, his memoir of 1920s Paris, Hemingway says he went to the art museum almost every afternoon after he finished his work for the day. As he studied the artworks, he says:

I was learning something from the painting of Cézanne that made writing simple true sentences far from enough to make the stories have dimensions that I was trying to put in them. I was learning very much from him but I was not articulate enough to explain it to anyone. [6, p.13]

What he had learned was how to leave things out and, thus, create an “impression” of something more. Hemingway’s spare prose style, thus, derived its energy from the innovative ideas of painters who working in a different domain, in a different time—yet still a presence in the creative life of the city.

Jumping continents and decades further into the future (to 1960s America), electrical engineer Billy Klüver, who was on the technical staff at Bell Labs from 1958-1968, became involved in New York’s avant-garde art scene—staging a famous set of concerts in 1966 titled “9 Evenings: Theatre & Engineering,” in which ten artists collaborated with thirty scientists and engineers from Bell Labs to create astonishing (for the time) music, dance, and theatre performances incorporating new technologies like video projection, wireless sound transmission, and Doppler sonar [19]. Klüver went on to co-found (with artist Robert Rauschenberg) Experiments in Art and Technology, a group dedicated to bringing artists and engineers together, and to write and edit several books, including *A Day with Picasso*, published in 1997 by MIT Press [20].

At Pixar Animation Studios, everyone in the company is encouraged to devote up to four hours per week to taking classes at Pixar University, the in-house training operation. With over a hundred classes—including a complete filmmaking curriculum, art classes, and creative writing workshops—Pixar University brings together employees from all areas of the company, from accountants to security guards, as well as people more directly involved in the creative end of the business. A *New York Times* article written in 2006 describes the philosophy of synergy and cross-pollination that drives Pixar University [21]:

At one class, the sixth session of a nine-week course called “Lighting and Motion Picture Capture,” the students represented an intriguing cross-section of Pixar employees: a post-production software engineer, a set dresser, a marketer, even a company chef, Luigi Passalacqua. “I speak the language of food,” he said. “Now I’m learning to speak the language of film.”

The evening’s subject was highly technical — the use of dimmers in the lighting of movies — but the session was spirited. The Pixar employees were also learning to see the company’s work (and their colleagues) in a new light. “The skills we develop are skills we need everywhere in the organization,” Mr. Nelson said. “Why teach drawing to accountants? Because drawing class doesn’t just teach

people to draw. It teaches them to be more observant. There's no company on earth that wouldn't benefit from having people become more observant."

Pixar Animation Studio's culture of interdisciplinary learning synergy plays a key role in the studio's astonishing continual improvement. In an interview published by *National Review Online*, Pixar's Craig Good said [22]:

Our technical artists are always being challenged by our story people. And it's amazing how they always rise to the occasion. Before *Nemo*, water was scary territory. Before *Monsters* fur was frightening. And before *The Incredibles* humans and clothing were, well, just about unthinkable. But our studio is designed with cross-pollination in mind, so there are technical advances which also inspire our story people. Are there still technical challenges? Hoo, boy and how. Those will never run out. Every movie has us living on what we cheerfully call "the bleeding edge."

Lesson #6 – A creative community allows for independence and self-direction

The most salient characteristic of artists' and writers' colonies (like The MacDowell Colony in New Hampshire) is that everyone does their own work and then meets over the evening meal to talk, in a way very similar to Steven Chu's lunch conversations at Bell Labs. At MacDowell, artists and writers stay in their quarters during the workday, not even leaving for meals (a basket lunch is delivered and left outside their doors). Likewise, because of their close proximity, artists in Paducah have formed a community that allows both the isolation necessary for creative production and the social interaction necessary for professional networking and informal opportunities to learn from each other.

In addition to its in-house classes, Pixar Animation Studios practices a form of collaboration they call "amplification." According to Randy Nelson, Dean of Pixar University, teamwork does not mean simply breaking down a job and divvying it up among team members. Each person does his own work but is encouraged and enriched by the presence of other talented individuals. Collaboration means not an assembly line but "a protocol that allows you not to get in each other's way" and results in "a bunch of human beings who are listening to each other, interested in each other, bring separate depths to the problem, bring breadth that gives them interest in the entire solution, allows them to communicate." [23]

Applying the lessons

The desired outcome of Criterion 3(i) is that students both understand the need for lifelong learning and *have the ability* to engage in it. A review of literature shows that engineering educators have identified skills necessary for lifelong learning. However, those skills (and their associated outcomes-assessment measures) are situated within the context of a formal education environment. Although we must, of course, assess student learning within this context, perhaps the specific program outcomes and performance

criteria for Criterion 3(i) should be tweaked to reflect the realities of our students' future lifelong learning environments. A review of literature *outside* of engineering education (i.e., economic policy documents of the European Union or magazines covering the “new” economy, such as *Fast Company*, *Wired*, and *Inc.*) indicates that lifelong learning in the 21st century will be a synthesis of savvy intellectual connections, social networking, and leveraging disparate human and natural resources.

If lifelong learning is defined *not* in terms of “keeping up” through continuing education (formal learning channels oriented toward achieving certification) but *rather* in terms of “staying ahead” of the curve through self-directed learning and developing the ability to create innovative ideas and products (informal learning channels not aimed at achieving certification), then we need to help students become their own teachers. Like Hemingway's Paris—a “moveable feast” of enriching experiences, social connections, and creative practices—an engineering education that has outcomes and performance criteria meant to forecast self-directed learning behaviors should encourage students to develop a capacity to enter new enterprises, intuit the problems/opportunities of the situation, assess their own resources, draw from their own experiences to make creative connections, correctly ascertain what they need to learn, and devise a strategy for reaching their learning goals.

Our challenge as engineering educators in the humanities, social sciences, and communicative arts is to offer insights from our fields that can help transform our students' understanding of lifelong learning and help them meet the Criterion 3(i) outcome in a way that goes beyond traditional ideas of continuing education. Applying the lessons learned from creative communities may help.

What causes a place to become a creative center? How does innovation happen? If “creativity” is a behavior, which is how the field of psychology describes it, then can this behavior be learned? Can creativity be taught? Can it be assessed?

Ideas for incorporating the lessons of creative communities into assessment plans fall into two categories: 1) design of the learning experience and 2) design of the performance criteria and assessment measures. Because these ideas are still at the work-in-progress stage, they are subjects for discussion more fully in a future paper. However, the following list comprises early thoughts on the topics.

Design of the learning experience.

1. **Make a playground.** This can be a place on campus or a “space” in a course syllabus. Inviting play is different from requiring it. It is the difference between recess and gym class—students are free to create their own experiences in the former but not in the latter.
2. **Become a maven in the middle.** Neither sage on the stage nor guide by the side is a good match for a creative community. If students are doing their own work and truly teaching themselves (alone and in groups), the teacher's role shifts to the

“locus” who mentors, provides social structure, helps people connect, secures necessary funding or supplies, brings the basket lunch. Without that key person at the center, the community has no linchpin; yet that central person is not the star of the community.

3. **Expect great things from students**, but don’t tell them what. As Steven Chu says, it is exhilarating and frightening to be given both freedom and expectations. Today’s students often expect to be given a rubric with every assignment, ideally with the requirements for success (what is required for an *A* grade, a *B* grade, etc.) clearly spelled out very specifically and maybe even very quantifiably.

It is more comfortable for both teachers and students if assignments have specific parameters and assessment criteria are objective rather than subjectively. Students don’t enjoy the messy and confusing search for what a teacher “wants” in an open-ended paper assignment; they are much happier when they can benchmark their own performance before turning in assignments by marking off discrete items from a rubric’s list of requirements (“includes abstract” – check; “uses three examples” – check). Likewise, grading is more comfortable for teachers when they can point to objective rubric criteria as the reason for a mediocre grade (fifteen typos and spelling errors, or two examples instead of the three required for an *A*); it is much more difficult to tell a student that his grade is a *C* instead of an *B* because his vocabulary is pedestrian, his ideas are ordinary, and his structure is incoherent .

However, if performance criteria are articulated, then expectations have been delimited and delimitations on the scope of student performance have also been articulated, whether intentionally or not. “Assignments without borders” is a scary place to be, but necessary for playing in a bigger sandbox.

4. **Allow/force students to fail** so they can learn resiliency. Randy Nelson, dean of Pixar University says that “the core skill of innovators is error recovery, not failure avoidance.” [23] This is a hard one, because the larger culture does not tolerate failure well. But, as noted by Henry Petrosky, who writes frequently on the history of design, failure (or, more specifically, *analysis* and then *remediation* of failure) is an important part of successful engineering. The challenge for classroom and curriculum is to reconcile a live-and-learn outlook with the desire to measure twice, cut once.
5. **Just say yes.** In the back of Peter Elbow’s groundbreaking 1973 book, *Writing Without Teachers*, is a remarkably little-noticed (considering the book’s fame) appendix essay titled “The Doubting Game and the Believing Game – An Analysis of the Intellectual Enterprise.” [elbow] The Believing Game asks students to accept something (a concept, a draft of a document) until a better “something” comes along, whereas the Doubting Game asks students to tear something down, and accept it only if it is still standing after the assault.

Randy Nelson (of Pixar) also stresses the importance of embracing new ideas, citing his background in improvisational comedy as key to understanding the concept of “amplification,” the concept underlying Pixar’s version of “collaboration.” An improvisational skit will come to a premature end if one player advances a scenario and the other player closes it off. The only way for a skit to work is for each player to grab and go with whatever the other throws into the mix, making quick-witted connections and spinning out the scenario until it ends.

Saying “yes” to everything until the best “yes” is settled upon is contrary to the way of thinking exemplified by the just-say-no scientific method, in which things can be absolutely falsified but never absolutely verified. However, if lifelong learning is an art, then the scientific method is the most appropriate way of discovering its truths.

Design of performance criteria and assessment measures. The following is a first-pass list of potential assessment measures of a student’s ability to engage in lifelong learning.

1. Student membership in professional organizations or hobby/special interest organizations, including level of involvement (meetings attended, offices held, etc.)
2. Use of social networking media, especially professional sources like LinkedIn or hobby/special interest groups. Also, the ability to
3. Mastery of something, in some field (not necessarily academic) – a hobby, an athletic skill, playing an instrument, etc.
4. Ability to identify problems or opportunities that can be solved or capitalized on.
5. Capacity for what the John Keats (the Romantic poet who wrote “Ode to a Grecian Urn”) termed “negative capability” – having the ability to tolerate “uncertainties, Mysteries, doubts, without any irritable reaching after fact and reason.”

Conclusion

Jobs’ 2005 address to Stanford University’s graduating class captures the tension between formal education and informal learning. Two different types of “learning societies” may emerge in response to the Criterion 3(i) emphasis on lifelong learning—one that would involve learning what someone else prescribes (certification) and the other that would involve learning whatever interests you. Each approach has value, but the first is focused on demonstrating competence and qualification, while the second is not directly focused on either.

Steve Jobs is reportedly such a perfectionist that he probably could never have brought himself to take the calligraphy class if he hadn't dropped out of school. Something with no hope of practical application would hardly have been the "perfect" elective to take, and if a perfectionist is faced with imperfect choices, he does without rather than make a mistake.

It is hard to accept seemingly pointless learning, especially in a field that values linear accrual of knowledge. But as Jobs says, you can't connect the dots looking forward. Informal, self-directed learning may lead nowhere—or, it may lead to true innovation, as in the design of the Macintosh. If innovation is what we want from a "thinking society," rather than mere competence, then the challenge for engineering education is to foster students' ability to engage in lifelong learning in the absence of an immediate payoff in terms of grades, certification, or other resume-enhancing qualification.

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