How Do You Recognize and Cultivate Potential Innovators?

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Technological innovation and the future U.S. economic well-being. In 2005, a bipartisan group of Senators and Members of Congress asked the National Academies to respond to the following questions:

> *What are the top 10 actions, in priority order, that federal policymakers could take to enhance the science and technology enterprise so that the United States can successfully compete, prosper, and be secure in the global community of the 21st century? What strategy, with several concrete steps, could be used to implement each of those actions?*

In response, the National Academies formed a committee of 20 distinguished Americans, headed by Norman R. Augustine, retired CEO of Lockheed Martin and former Undersecretary of the Army. The committee included other current and former corporate CEOs, university presidents, scientists (including three Nobel Laureates), philanthropists, former government officials, and education leaders. [1] In 2005, this committee published a provocative report entitled Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future. [2] The committee concluded that a primary driver of the future economy and concomitant creation of jobs will be ***innovation***, largely derived from advances in science and engineering. While only four percent of the nation's workforce is comprised of scientists and engineers, this group disproportionately creates jobs for the other 96 percent. [3]

The committee was reconvened in 2010 to review the nation's progress on this agenda. They concluded that in the intervening five years, little progress has been made in the U.S., while other nations have made significant improvements. They concluded that innovation remains our best hope for the future:

> *"The only promising avenue for achieving this latter outcome [economic prosperity], in the view of the Gathering Storm committee and many others, is through innovation. Fortunately, this nation has in the past demonstrated considerable prowess in this regard. Unfortunately, it has increasingly placed shackles on that prowess such that, if not relieved, the nation's ability to provide financially and personally rewarding jobs for its own citizens can be expected to decline at an alarming pace. The recommendations made five years ago, the highest priority of which was strengthening the public school system and investing in basic scientific research, appears to be as appropriate today as then."* [4]

Of many recent findings reported by the committee, the following three help to provide context for the growing concerns: [5]

- In 2009, 51 percent of *United States* patents were awarded to non-United States companies.
- In the 2009 rankings of the Information Technology and Innovation Foundation, the U.S. was in 6th place in global innovation-based competitiveness, but ranked 40th in the rate of change over the past decade.
- United States consumers spend significantly more on potato chips than the government devotes to energy research & development.

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[1] The Committee on Prospering in the Global Economy of the 21st Century: An Agenda for American Science and Technology, NAS/NAE/IOM.
[2] NAS/NAE/IOM, Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future, National Academies Press, 2007. (The initial report was released in 2005, with the final edited book issued in 2007. It is available at Amazon.com and other sources.)
[3] NAS/NAE/IOM, Rising Above the Gathering Storm, Revisited: Rapidly Approaching Category 5, National Academies Press, 2010, pp. 2-3. (Also available at Amazon.com or other sources.)
[4] Ibid, p. 5.
[5] Ibid, pp. 6 – 7.

What is innovation? For purposes of this conversation, I will attempt to distinguish innovation from creativity. First, creativity may be defined as the process of generating original ideas and insights that have value. [6] Innovation may then be defined as the process of having original ideas and insights that have value, and then implementing them so that they are accepted and used by significant numbers of people. By this definition, a major innovation is one that is so successful that soon after its introduction few people can even remember what life was like before the innovation was introduced.

Some examples of major technological innovations of the 20th century illustrate this point. The automobile, telephone, airplane, computer, internet, wireless communication, etc. are all examples of highly successful innovations that changed the way we live in profound ways.

The important point here is that innovation is not the same thing as creativity. Having a novel idea is necessary but not sufficient to establish an innovation. As pointed out in a previous paper, ideas which become innovations seem to always require the simultaneous achievement of feasibility, viability, and desirability. [7]

However, to become an innovation requires much more than an idea. In particular, a great deal of effort—involving testing and refinement, gaining acceptance, obtaining funding, marketing, manufacturing, distribution, etc.—is necessary to transform a novel idea into an innovation. Thomas Edison once pointed out that genius requires 1% inspiration and 99% perspiration. [8]

Summarizing, engineering innovators are people who envision what has never been, and then do whatever it takes to make it happen. They are creative, but they are also motivated to take initiative, think entrepreneurially, be resourceful, and remain persistent in order to complete the task. This requires a set of attitudes, behaviors and motivations that distinguish innovators from others who may just have big dreams.

What some others have to say about innovation and innovators. The importance of innovation is so widely recognized that it has been the subject of many published articles and conferences in many fields, including engineering and science, psychology, education, management and others. As noted above, innovators require more than mastery of a body of facts or information; they also have certain human skills and motivations that are prominent in determining their success. [9] As a result, it is difficult to describe innovators without a context or culture. In order to provide some insight into this complex issue, I decided to interview several influential and key thinkers about innovators and to supplement this with a few excerpts from the vast literature in this field. Presented here are the results of this brief investigation.

- ***Sir Ken Robinson*** (creativity expert): "…*There is a tendency to think of creativity as a solo performance, but for the most part, it's not. It's about people working together*. …" [10]

- ***Howard Gardner*** (Harvard University): What is the best way to go about identifying young people with high propensity for innovation? *"I would recommend having a substantive conversation with candidates focused on examples of projects they have worked on that demonstrate depth of knowledge, flexible thinking, and perseverance in completing a task. I would even consider asking them to send me a written description of their work on such projects, if there isn't enough time to explore this adequately in an interview. I would not be in favor of relying on answers to a set of impromptu questions in an interview setting. I fear that such*

[6] Robinson, Ken, Out of Our Minds: Learning to be Creative, Capstone Publishing (Wiley), 2001.
[7] Miller, Richard K., "*From the Ground Up: Rethinking Engineering Education for the 21st Century*," Proceedings of the Symposium on Engineering and Liberal Education, Union College, NY, 2010.
[8] Thomas A. Edison, quoted in Harpers Monthly, September 1932.
[9] Malcom Gladwell, in his book Outliers, would also add that successful innovators are often the beneficiaries of many other factors beyond their control—such as being born at the right time, etc.—so a degree of good fortune is almost always involved in stories of extraordinary success and innovation.
[10] Wujec, Tom, Ed., Imagine Design Create: How Designers, Architects, and Engineers Are Changing Our World, Melcher Media, NY, 2011.

questions often test random or superficial knowledge rather than the characteristics that lead to innovation." What can institutions do to enhance and cultivate the ability of young employees to become innovators? *"Institutions should pay careful attention to the alignment between implicit and explicit messages. While no one has bad things to say about innovation today, not everyone is serious or authentic in the way they implement and support it internally. In schools, the focus should be on encouraging students to ask questions, seek challenges, and then rewarding them for this behavior. In the workplace, leaders must realize that if workers who are too judgmental and brutal are getting ahead, then this sends the wrong message to those who are really trying new ideas—which are likely to fail in the initial stages. Whether in school or in an organization, it is optimal to have leaders who themselves know the ins and outs of innovative thinking."* [11]

- ***Tony Wagner*** (Harvard University): "*Innovation may be categorized as either incremental or disruptive, and these require different skill sets. In thinking about the process of preparing innovators, it seems to me that the underlying culture and assumptions in research universities may constitute significant barriers to the production of innovators. For example, American culture celebrates individual achievement, not collaboration. But innovators almost always establish successful teams, and it is usually counter-productive to focus on individual contributions. Next, universities reward deep knowledge and analytical ability, and this is the presumed pathway to producing innovators. But, innovators are almost always highly interdisciplinary and they often find academic disciplines limiting in their thinking. (Perhaps as a result, many of them drop out of college and don't graduate.) Finally, extrinsic rewards dominate in mainstream higher education. But, innovators are usually motivated instead by rewards that are better described as intrinsic. Regarding cultivation of intrinsic motivation, children are generally born with high levels of intrinsic motivation and are driven by curiosity and inquisitiveness. Parents of innovators seem to encourage this by providing lots of unstructured play time. The developmental path of innovators seems to progress from play to passion to purpose.*

  Now, regarding the assessment of young engineering graduates as innovators, it may simply be premature to come to any firm conclusions. However, corporate interviewers would be wise to look for wide experiences, preferably involving significant travel. In addition, they should pay careful attention to the way the candidate frames and describes the problems s/he has worked on, and on the process used to solve them. It always takes time for significant innovations to develop, and for serial innovators to demonstrate their ability. Instead, it may be more productive at this stage to focus on the aspects of institutional culture that support the development of innovators. These include independent study, teamwork and leadership, project-based learning, and entrepreneurial thought and action." [12] (Many of these concepts will appear in his forthcoming book, Learning to Innovate, Innovating to Learn, which will be published by Scribner next spring.)

- ***Mark Somerville*** (Olin College): "*Preparing successful engineering innovators requires both appropriate educational content, involving a combination of feasibility, viability, and desirability, and also the skills to innovate. These skills include creative thinking skills, effectual (means-based) reasoning, convergent and divergent thinking processes, and reflection-in-action. Viewed through this framework, it is clear that most engineering curricula are not designed to support innovation. Research in creativity and innovation suggests that the key characteristic that distinguishes entrepreneurs and innovators is their intrinsic motivation—their <u>will</u> to innovate. Entrepreneurs and innovators are highly self-directed, are willing to take initiative and assume appropriate risks, and display high levels of self-efficacy (the strength of belief that one can complete a task). Thus, preparing graduates to be innovators and entrepreneurs requires not only developing their knowledge and skills toward this end, but also helping them to become self-directed, confident, intrinsically-motivated individuals.*" [13]

[11] Gardner, Howard, personal interview, April 19, 2011.
[12] Wagner, Tony, personal interview, April 13, 2011.
[13] Somerville, Mark, personal interview, May 4, 2011.

- ***Teresa M. Amabile*** (Harvard University): *In a study of* "*scientists working in research organizations [with] doctorates and masters degrees…[f]our social-psychological factors seemed most important in facilitating the realization of creative potential: (1) high responsibility for initiating new activities, (2) high degree of power to hire research assistants [different in the sciences], (3) no interference from [an] administrative superior, and (4) high stability of employment*[14]…"

  "[H]uman motivation toward work can be categorized into two distinct types: intrinsic motivation, which arises from the intrinsic value of the work for the individual (such as its interest value) and extrinsic motivation, which arises from the desire to obtain some outcomes (such as rewards that are apart from the work itself).[15]*…Intrinsic motivation is conducive to creativity; controlling extrinsic motivation [by authority] is detrimental to creativity, but informational or enabling extrinsic motivation can be conducive, particularly if initial levels of intrinsic motivation are high.* [16]*…"*

- ***Charles Vest*** (National Academy of Engineering; MIT): "*Innovation and invention are two different things. Innovation involves moving ideas into society and the marketplace, and can involve either doing new things or doing old things in a new way. (Academia sometimes forgets about the importance of the marketplace.) Innovation is also distinct from entrepreneurship. Characteristics of innovators include the ability to identify societal needs, and the leadership and communication skills necessary to move new inventions into society in spite of resistance. In addition, successful innovators have a natural empathy for others which enables them to adopt the perspective of others. This type of communication training is not common in engineering education today. One of the major challenges in educating innovators is to get students to think hard about realistic and complex problems without extinguishing their self-confidence and ability to generate big, wild ideas."* [17]

- ***John Seely Brown*** (USC; Xerox): "…*the rapid pace of change in technology and the way business is conducted means that students must have the capacity to learn independently, work comfortably on cross-disciplinary teams, and know how to use multiple methods for thinking through problems—mathematical, linguistic, artistic, and so on…. [Seely Brown] advocates a number of very different learning environments, such as the classroom as architecture or design studio. He describes it this way: 'All work in progress is made public…every student can see what every other student is doing; every student witnesses the strategies that other students use…and there is public critique, typically by the master and perhaps several outside practitioners'…[success in complex environments requires] extremely good pattern recognition, sense-making in confusing environments, and multitasking…Continuous decision-making in conditions of uncertainty is the essential skill* [18]*…"*

- ***Vinton G. Cerf*** (Google): "…*What conditions give rise to innovation and facilitate its transforming effects? Contributing factors include the freedom to pursue ideas, the freedom to fail, and the freedom of access to information in the broadest sense…Young people should understand and experience the thrill of science and discovery…Children learn best by seeing and doing, not by memorizing* [19]…"

- ***Charles Fadel*** (Cisco Systems): "*Some large companies don't invest much effort in deliberately searching for innovators, but rather rely on their reputation to bring the right people to them for*

[14] Amabile, Teresa, Creativity in Context: Update to the Social Psychology of Creativity, Westview Press, 1996, pp. 210-211.
[15] Amabile, Teresa, *Entrepreneurial Creativity Through Motivational Synergy*, J. Creative Behavior, V. 31, 1997, p. 20.
[16] Ibid, p. 23.
[17] Vest, Charles, personal interview, April 25, 2011.
[18] Kao, John, Innovation Nation: How America Is Losing Its Innovation Edge, Why It Matters, and What We Can Do to Get It Back, Free Press, NY, 2007, pp. 105-106.
[19] Cerf, Vinton G., *How to Fire Up U.S. Innovation*, Opinion, New York Times, April 12, 2011.

interviews. Of course, there are exceptions to this. The engineering manager, not a human relations staff member, often makes the decision on which applicant to select. Interviews are usually obtained by screening written resumes for certain key words, and the decision is often made mostly on the basis of exposure to a certain body of knowledge rather than personal characteristics or skills. In general, there is an increasing awareness in industry of the importance of special types of communication skills, and some companies are attempting to measure these. However, the metrics are not well developed yet and they are not widely implemented. To foster innovation within a large company like Cisco, a special division was set up to operate as a start-up enterprise. Cisco employees who are interested in innovation can self-identify and seek affiliation with this unit as well as contribute product or feature ideas to this unit or others. Any employee within Cisco can contribute to the innovation in this division through email communication or a wiki set up for this purpose. Regarding Christensen's taxonomy of innovation as primarily incremental or radical, most innovation is incremental, and this can be accommodated within large companies through processes as just described at Cisco. However, a small proportion of innovation requires radical thinking and often deviate from the company's core mission and competencies, so this usually is better found in a different culture, like that in a small start-up company. Radical innovators usually don't stay long in large companies for this reason." [20]

Several major themes emerge from these narratives. Innovation goes beyond creative ideation to include implementation of new things and requires persistence. Innovators are flexible, multidisciplinary thinkers who are perceptive of the needs of others and able to identify opportunities. They often prefer projects with a purpose, work with others in teams, and are influential in their interactions. They are adaptable, independent learners who seek out and absorb new concepts from outside their comfort zone. They are entrepreneurial and take initiative without hesitation. They usually do their best work when driven more from intrinsic motivation than by extrinsic rewards or penalties.

(Of course, these are broad generalizations that sometimes over simplify reality. Innovators, after all, are real people, and these characteristics describe a wide range of different people. For example, one of the major themes is that autonomy, self-direction, and intrinsic motivation can play an important role in enhancing creativity and innovation in the workplace. This is based on careful but somewhat limited experimental research and is regarded by many as practical advice in managing the work environment in industry. In the context of the experiments, this concept seems quite sound, although it is also important to realize that there may be limits to its applicability. Simply providing all employees with high levels of autonomy and freedom from extrinsic demands does not necessarily result in increases in innovation. For example, Jon Marcus recently completed a history of American higher education for the past 400 years [21] and reported that nearly all major innovations in American higher education (e.g., modern languages, experimental science, access to education for all, etc.) required the establishment of entirely new institutions to initiate. Furthermore, the innovations were consistently resisted by the faculty at established universities—sometimes for many decades after they were introduced. Plato is credited with the observation that "necessity is [often] the mother of invention." [22] Of course, this does not mean that organizations should deliberately impose hardship or extrinsic demands as a strategy to spark innovation!)

Preparing exemplary engineering innovators. Established in 1997, largely in response to such national concerns about the need for better prepared engineers, Olin College's mission is to "*prepare students to become exemplary engineering innovators who recognize needs, design solutions, and engage in creative enterprises for the good of the world.*" Furthermore, Olin College's aspiration is to "*redefine engineering as a profession of innovation encompassing (1) the consideration of human and societal needs; (2) the creative design of engineering systems; and (3) the creation of value through*

[20] Fadel, Charles, personal interview, April 20, 2011.
[21] Marcus, Jon, *Old School: Four Hundred Years of Resistance to Change*, Proceedings, Reinventing the American University, American Enterprise Institute, Washington, DC, June 3, 2010.
[22] Plato, The Republic, Athens, 427-347 BC.

entrepreneurial effort and philanthropy. The College is dedicated to the discovery and development of the most effective educational approaches and aspires to serve as a model for others." (Underline added.)

Olin stands out in comparison to most other engineering schools for its high level of commitment to preparing engineering innovators, even attempting to influence the definition of the field of engineering as a profession of innovation. The distinctive educational approach at Olin was developed to support this mission. While we hope that our efforts will result in an increase in the percentage of our graduates who go on to become successful engineering innovators, it is equally important to us that every Olin graduate is prepared with the knowledge, skills, and motivations to become a force for innovation and innovative thinking in the workplace—no matter where they spend their career.

What we know today about Olin graduates and their careers. The metrics we have on Olin's 343 alumni provide a glimpse into the types of career outcomes to which our graduates are headed. The average age of Olin alumni ranges from 23 to 27. About 10% are named on U.S. patents (or patents pending). Another 10% have been involved in starting a new enterprise or business.

At this point, about 40% of Olin alumni have pursued graduate study, predominantly in engineering and the sciences. (The number seems to increase each year as more alumni decide to return to school for advanced education.) However, a small but steady stream is headed to medicine, law, and business each year. About 20% of those pursuing (or having completed) graduate education do so at three institutions: Harvard, Stanford, or MIT. Of those alumni who have enrolled in graduate school, 17% have won the prestigious National Science Foundation Graduate Research Fellowship in national competition. In addition, Olin College was named a "top producer" of Fulbright Scholarship winners in 2010.

The employer of the largest number of Olin alumni is Microsoft, followed by Google. Many of our graduates prefer to work for companies with a start-up or entrepreneurial culture. We survey employers about the performance of our alumni in comparison to graduates of other schools two years after graduation. At the two year mark, the results have been very good with about half of employers reporting to us that Olin alumni perform at a level expected of employees with 3 – 5 years of experience. The open comments from employers are even more outstanding, often mentioning special ability of Olin alumni in the areas of project management, teamwork, and independent problem solving.

The challenge of knowing whether Olin graduates are prepared to become exemplary engineering innovators. Olin College is not only committed to preparing engineering innovators, but also to continuous improvement. This requires assessment and frequent adjustment of the learning process to achieve the desired outcome. As a result, we are concerned about measuring our progress and creating systematic improvements.

Of course, a strong case could be made that it is simply too early to make any firm conclusions about the degree to which Olin alumni are likely to become successful innovators. In fact, the entire concept of recognizing and measuring individual innovators is extremely complex and likely to be error-prone, given both the short period Olin alumni have been out of school and the limited availability of reliable knowledge about the characteristics of young innovators. Determining what is the most important factor that led to the success of an outstanding individual is a bit like asking why it is that a particular tree happens to be the tallest in a forest. The answer, of course, has something to do with the genetics of the tree, but it is likely to have as much or more to do with the ecology of the location where it is planted. The availability of nutrients, sunlight, the proximity and height of nearby trees, the availability of water, and the presence or absence of pests and diseases often play an obvious and overwhelming role in determining which tree grows to be the tallest. [23] It is likely that our efforts to develop metrics for innovation among Olin alumni will face similar or greater challenges. Nevertheless, the challenge of recognizing and cultivating potential innovators is so important that we are committed to doing what we can to learn about the possibility of measurement and the process or cultivation of innovation among engineering students.

[23] Gladwell, Malcom, Outliers: The Story of Success, Little, Brown and Company, NY, 2008, pp. 19-20.

Our attempts in this area are significant, but not yet mature. We are beginning to work with our partners at the University of Illinois at Urbana-Champaign to develop surveys and metrics that are aimed specifically at characteristics of innovators. Survey questionnaires from Olin to employers ask questions intended to explore the comparative strengths and weaknesses of Olin graduates in such areas as taking initiative, working in teams, demonstrating leadership potential, applying basic business concepts, overall technical competence, engaging in independent learning, competence in writing, etc. As noted in the work of the National Academies cited earlier, many companies and other organizations are currently focused on enhancing the innovation capacity of the U.S. Some of them must have considered the problem of how to recognize young engineers who are good candidates to become successful innovators in their companies. This is—or should be—a staff recruitment issue, and perhaps some companies have developed metrics that could be helpful to Olin College at this stage in our development.

In addition, after recruiting the best available talent, it is obviously important to cultivate those within the organization who are likely to become innovators in order to maximize innovation capacity. Some corporations and other institutions have developed various programs and approaches to accomplish this, from which we could also learn.

Question. Given the importance of technology innovation to the national economy, the mission of Olin College to prepare students to *become exemplary engineering innovators*, and the discussion in this paper about what innovation and innovators are:

1. What are your perspectives on the important characteristics of innovators and innovation-supportive environments?

2. Given these perspectives, what should Olin be measuring in order to continue improving and meeting our mission?