How Will Internet-Based Instruction, Social Networking, and Mass Communication Change Undergraduate Engineering Education?

by
Richard K. Miller

> *"If men learn this [writing], it will implant forgetfulness in their souls; they will cease to exercise memory because they rely on that which is written, calling things to remembrance no longer from within themselves, but by means of external marks." Books, "by telling them of many things without teaching them" will make students "seem to know much, while for the most part they know nothing, and as men filled, not with wisdom, but with the conceit of wisdom, they will be a burden to their fellows. Then anyone who leaves behind him a written manual, and likewise anyone who takes it over from him, on the supposition that such writing will provide something reliable and permanent, must be exceedingly simple-minded."*—Plato (quoting Socrates on the advent of writing and books) in Phaedrus [ca. 370 BC][1]

Executive Summary. The recent decision by Stanford, MIT, Harvard and other universities to provide massively open online courses (MOOC) at no cost to many thousands of students located across the globe raises questions about the potential for internet-based instruction to change the nature of undergraduate education in engineering. Furthermore, with steadily rising costs of traditional higher education, it raises questions about the sustainability of the business model for residential undergraduate programs. While it may be too early to answer these questions with certainty, their strategic importance is compelling. This short paper provides a discussion of several dimensions of these issues and includes summaries of recent interviews with a range of individuals currently involved in experiments with internet-based learning.

Introduction. In recent years, the widespread availability of high speed internet connectivity, increasingly powerful and inexpensive wireless devices, and an explosion in media-rich social networking opportunities has created a fundamental change in the way we communicate, learn, and behave. For example, the Arab Spring last year was enabled to a significant extent by widespread social networking. "Flash mobs" that assemble in response to informal calls for action posted on the internet are now a common occurrence on the evening news, with activities that range from convergence on a particular store in order to steal merchandise, to convergence on a location to provide spontaneous aid to those in need. Facebook has become a compulsion for social connectivity among young and old alike, fueling an explosive rise in the financial value of the company. Twitter—which facilitates short messages (140 characters or less)—has replaced email as the popular form of electronic communication.

In higher education, YouTube, Google and many other similar sites have become ubiquitous sources of basic information on almost every subject fundamentally altering the role of faculty members as the ultimate source of information. Good teaching today is much less about providing information than it is about "sense-making" and contextual understanding. Open-source web sites such as Wikipedia, which rely on public participants to spontaneously create and maintain accurate information, have become as authoritative as the Encyclopedia Britannica in the last century. The recent emergence of The Khan Academy as a resource consisting of video mini-lectures and tutorials on everything from calculus to world history enables anyone with internet access to obtain a working knowledge of many subjects—including practical applications—at home, at their own pace, and at no cost. Most middle class young children in the U.S. today grow up immersed in digital media and interactive technology, often leading to such rapid development of remarkable skills with internet technology that it often seems intuitive to those of us in previous generations.

The acceleration with which these changes are happening is remarkable and has fueled uncertainty and speculation on the long-term effects these trends will have on the very nature of higher education. For

[1] Parker, Jo Ellen, *"Socrates on Technology*." LiberalArtsOnline, 14 May 2001 (Vol. 1, No. 3.)

example, the MIT Open Courseware project more than a decade ago provided access to detailed course materials (including syllabus, homework, exams, etc.) for a large proportion of the courses offered at MIT in almost any subject, at no cost. While this program was revolutionary at the time, it provided only static rather than interactive access to course materials, with no opportunity to ask questions or obtain feedback on your work. However, last year Stanford University launched an experiment in which a rigorous Stanford course in Computer Science was offered at no charge to anyone on the internet, including the opportunity to ask questions, obtain personalized feedback, and even receive some certification of completion. The course attracted more than 100,000 participants on the internet, worldwide, and has led to more experimentation at Stanford, formation of a new coalition of major universities to expand this experiment, and two new spinoff ventures (Udacity and Coursera) in Silicon Valley. In addition, MIT recently launched a somewhat similar experiment, called the MITx program, in which a small number of MIT courses are offered at no charge on the internet, also including the opportunity to ask questions, obtain feedback, and ultimately to receive some form of certification of completion. Leaders at both MIT and Stanford recently reported that they feel the developments in this area are likely to be transformative, but they are uncertain where the changes will lead. They both feel that even though they do not have a clear picture of what these changes will bring, they feel compelled to engage now in experiments that will help them learn about and shape these new developments.

In the last few weeks, Harvard and MIT announced a new not-for-profit venture edX to provide free online access to a range of courses on the internet. This new partnership is intended to provide a platform for research on how people learn over the internet as well as provide free access to current courses at these top universities for anyone across the globe. It was funded by a commitment of $60 million from the institutions and will be jointly managed.[2]

The recent launch of these massive online efforts has attracted substantial attention from the national media. For example, David Brooks[3] wrote that "What happened to the newspaper and magazine business is about to happen to higher education: a rescrambling around the web….Will online learning diminish the face-to-face community that is at the heart of the college experience?...People learn from people they love and remember the things that arouse them…"

Also, Thomas Friedman explained the new online learning in another article[4]. He spoke with Andrew Ng at Stanford who said " 'I normally teach 400 students,' …but last semester he taught 100,000 in an online course on machine learning. 'To reach that many students before,' he said, 'I would have had to teach my normal Stanford class for 250 years.'…Big breakthroughs happen when what is suddenly possible meets what is desperately necessary. The costs of getting a college degree have been rising faster than those of health care, so the need to provide low-cost, quality higher education is more acute than ever….Says [Daphne] Koller [of Stanford]: 'It will allow people who lack access to world-class learning—because of financial, geographic or time constraints—to have an opportunity to make a better life for themselves and their families.' "

One of the most respected observers and authors in the field of business innovation is Professor Clayton Christensen of Harvard Business School. His research on disruptive innovation in many fields reveals a pattern in which an emerging, low cost, low quality alternative to the proven but expensive best product in an industry is ignored at first. As the low quality alternative goes through a long period of improvement it ultimately achieves a quality that is good enough to satisfy the majority of industry customers. By the time existing incumbents realize the threats posed by these lower quality alternatives, it is often too late to develop a viable response. He reports that the emergence of internet-based learning technology broadly defined has created the capability to disrupt higher education[5,6]. He believes that it is only a matter of time until learning through this new technology will become at least as effective as the long traditional

[2] Lewin, Tamar, "*Harvard and M.I.T Team Up to Provide Free Online Courses*," New York Times, 2 May 2012.
[3] Brooks, David, "*The Campus Tsunami*," New York Times, 3 May 2012.
[4] Friedman, Thomas L., "*Come the Revolution*," New York Times, 15 May 2012.
[5] Christensen, C.M., et al., Disrupting Class: How Disruptive Innovation Will Change the Way the World Learns, McGraw-Hill, 2010.
[6] Christensen, C.M., et al., The Innovative University: Changing the DNA of Higher Education from the Inside Out, Josey-Bass, 2011.

approach in which faculty members lecture as the "experts" and students are treated as passive recipients of knowledge—and perhaps even more important, the new approach will be much less expensive. He believes this trend has the potential to fundamentally change the business model for higher education.

Education vs. Training. There are many different kinds of knowledge and of learning. For example, learning to drive a car, or diagnose a disease, or design an airplane, or perform a violin solo at Carnegie Hall all involve education. However, these activities are so different that the type of education used is currently very different for each activity. Furthermore, different individuals often learn best in ways that are unique to them. For example, some people are naturally "auditory learners" while others are primarily "visual learners." It is well known that one-size-fits-all approaches to teaching do not produce the best results in learning.

Professor Woodie Flowers at MIT has described this spectrum of learning as a continuum that ranges from "training" on one end to "education" on the other. In the context of engineering education, he points out that the learning objectives in some traditional engineering science and mathematics subjects within the engineering curriculum involve the development of skills among the students at performing certain calculations in response to carefully formulated problems. Such skills development is particularly amenable to digital learning methods over the internet. On the other hand, other subjects, such as conceptual design, problem diagnosis, capacity for judgment, and learning transfer from one domain to another require more reflection and "sense making" of the context as well as creativity in order to achieve a degree of mastery.

Furthermore, he feels that the potential exists for advanced digital media and entertainment technology to richly enhance the presentation of knowledge in many traditional subjects. For example, imagine a Steven Spielberg video production of the fundamentals of cell biology, featuring the nation's most gifted biology lecturer together with 3-D video simulations of basic biological processes within a cell. Such visualization provides the opportunity for the student to "experience" the new material in ways that have never been possible before. Viewing such engaging and visually stimulating presentation of the basic material could substantially enhance the understanding and interest among students in this technical field. Technology might be able to reduce the teaching of this basic subject (and many others) to that of a form of "training" that is largely self-paced and enabled by digital technology. It could also free faculty members around the nation from the obligation to try to replicate this material themselves in a classroom or auditorium by standing in front of students with a chalkboard. Instead, faculty members could use their time for more engaging interaction with students through personal questioning and coaching, directing student group projects, and helping students reflect and make sense out of the material. This higher learning activity he would describe as "education."

Professor Flowers believes that while there is great potential for enhanced media-rich instruction technology to improve educational "training," he does not believe that this will replace the total immersive experience that is only available in a residential learning environment, for the "education" end of the learning spectrum. In his own words: *"Evaluation of education is a complex task, but I believe that if we could objectively evaluate education, well-designed residential programs would be demonstrably superior."*[7] The optimal approach he envisions is a "blended" learning environment, in which technology resources are used for the training aspects and human interaction is used for the education aspects. Again, in his own words: *"New media technologies offer the academy the opportunity to create positive changes. We can use new media for training and use humans for education. This would result in residential programs being used only for things that require presence. Training does not justify the costs of most university experiences. Education does."*[8]

[7] Flowers, W., "*New Media's Impact on Educational Strategies*," Forum Futures 2002, (available at net.educause.edu/ir/library/pdf/ffpiu016.pdf) p. 105
[8] Ibid, p. 110.

Innovators vs. Applied Scientists. Olin's mission is to produce "exemplary engineering innovators." Innovators are people who envision what has never been, and then do whatever it takes to make it happen. The heart of this type of activity is vision, creativity, teamwork, design, and perseverance. Of course, it also involves familiarity with a body of knowledge in more traditional technical subjects, as well as the ability to manufacture, distribute, finance, market, and support products in new markets—but without the insightful new concept and breakthrough idea—no matter how efficient and scientifically advanced you are—you are unlikely to produce game-changing innovations.

Learning to be an innovator is enhanced by studio-based learning and pedagogies that are shared with art schools. More than a curriculum and pedagogies, it requires an "ecosystem" and a learning environment. In the Flowers learning spectrum, the techniques required to develop these abilities clearly require more education than training. In his new book on creating innovators[9], Tony Wagner of Harvard University reports that the development of innovators follows a personal trajectory from *play* to *passion* to *purpose*. He presents a clear description of the personal characteristics of young innovators in several domains through detailed case studies that follow their personal development from childhood through higher education to early career. The concept of a learning ecosystem is not traditional within engineering education today. It involves building a set of cultural values and social relations that encourage creativity and risk taking, as well as the pursuit of excellence. It is characterized by a community that simultaneously reports that they have never worked so hard in their life, yet there is nothing else they would rather be doing. It is hard to imagine how this type of special learning environment could be produced without intense personal interaction and mentorship from experienced faculty members who are skilled in coaching small interdisciplinary teams of students.

Will Technology Reduce the Cost of Education? One theory regarding the role of digital media and internet-based instruction in the future is that it will substantially reduce the cost of an engineering education. This is one of the primary conclusions of the Christensen disruptive innovation theory. Significant cost reduction could occur if effective internet-based instruction is eventually used to displace faculty members in "training" engineering students in the more traditional subjects. A strong case could be made that this is beginning to happen now and will likely continue resulting in a net reduction in the amount of faculty time required for students to achieve a given level of mastery of these subjects. It could conceivably lead to an overall shortening of the number of semesters required to earn the bachelor degree.

However, there are several implicit assumptions built into this reasoning that are as yet unproven. For example, it is assumed that when faced with the widespread ability to achieve the current learning objectives in a subject very efficiently, freeing up class time that was previously required to teach subjects in more tedious and ineffective ways, that the faculty in charge will not use the new-found class time to simply raise the bar on the learning objectives and add new material to the course syllabus. Even if new subjects are not introduced, faculty members might choose to spend more time working with students in small groups in coaching them to achieve a higher level of understanding and "sense making." If this happens, then any costs saved through applying new teaching technologies are immediately reinvested in a simultaneous effort to improve the quality of the education provided[10].

In addition, the costs associated with buying and maintaining a state-of-the-art internet-intensive educational system are not insignificant. Experience with previous generations of internet teaching technologies have proven quite costly, including not only new hardware and software, but also additional expert staff needed to help the faculty develop and implement effective technology-enhanced pedagogies.

[9] Wagner, Tony, Creating Innovators: The Making of Young People Who Will Change the World, Scribner/Simon & Schuster, 2012.

[10] Alternatively, research universities might decide not to reinvest the faculty time in enhanced undergraduate education, but rather invest this additional time in Ph.D.-level research. If that happens, then the cost of an undergraduate education is also unlikely to be reduced.

When the goal is to maximize the quality of the education (the primary objective of a school like Olin College), many educators are advocating for a hybrid approach in which internet-based pedagogies are used for the *training* end of the course spectrum, and personal mentorship and coaching with faculty members is used at the *education* end of the spectrum. In this case, it is quite possible that the net costs of education will be increased by the introduction of new technologies rather than decreased.

Residential Education. As the availability of free and high quality online courses increases, it is possible that an increasing number of potential college students will decide to stay at home and enroll in courses at little or no cost without attending a residential college. It is possible that one day they may be able to learn the course content from online sources as well or better than they would from attending a traditional college. In addition, an increasing number of universities may decide to recognize such online learning with certification including a formal college degree (as some institutions have done for many years).

This raises an important question whether schools like Olin College—that are dedicated to providing an immersive team-based learning in which all students are required to live on campus for all four years—will lose a significant number of promising students because they doubt the value of such a residential experience is worth the substantial added cost. Since Olin's mission is to prepare exemplary engineering innovators, we believe that the residential experience and immersive teamwork environment is an essential part of the learning experience. However, it is possible that one day significant numbers of prospective students will not agree with our conclusion and choose instead to only take courses via the internet.

What Others Have to Say. In an attempt to provide a range of perspectives on this issue, I contacted several recognized leaders in the education of technology innovators in the last few weeks to ask them what they think about the basic issues outlined in the questions at the end of this paper. Reported here is a brief summary of the discussions that ensued.

Lori Breslow[11] "In my twenty years at MIT, there has never been so much interest and activity in education as in the last few months, since MITx (and then edX) was launched. The interest among a wide cross section of faculty here is substantial.

The awareness of the potential of online learning to fundamentally change the relationship between faculty and students has never been greater, and as a result, a growing minority of faculty members realizes they are not simply 'purveyors of information,' but can become more engaged with students to foster their learning. As documented in a recent article in the Chronicle of Higher Education, many students now graze the internet for their own explanations and sources of information and they prefer this to lectures or videos prepared by the instructor. Furthermore, the well-known Bloom's 2 sigma effect (Benjamin Bloom, 1984) showed conclusively that the average student tutored one-to-one using mastery learning techniques performed a full two standard deviations above the average student in a conventional classroom environment without a tutor. With online materials, we have within our grasp the possibility of providing every student with the kind of tailored feedback he/she could receive from a personal tutor.

Blended learning approaches in which some aspects of internet-enhanced and autonomous learning methods are combined with more personal one-to-one and team-based discussion and guidance are emerging as methods that allow students to reach intended learning outcomes. For example, when faced with a wide range of levels of student preparation, faculty members can now direct the least prepared to obtain effective remedial instruction at such websites as the Khan Academy, and they can provide more prepared students with additional challenging material. Eventually, this might lead to the development of autonomous software that functions as an effective 'intelligent tutor.' If this eventually happens, it could conceivably improve both the quality of learning outcomes and reduce cost. This would be a sought-after

[11] ***Dr. Lori Breslow*** is the Director of the Teaching & Learning Laboratory at MIT and is Senior Lecturer at the MIT Sloan School of Management. She is an internationally recognized expert in the development and diffusion of pedagogical and curricular innovations and their assessment and evaluation.

resource for faculty in the STEM disciplines who often struggle with a wide range of student abilities and interests within one course. It is hard to predict, though, when this might become a realistic possibility.

However, I personally do not believe that residential learning environments will be threatened by the development of online learning for the foreseeable future. We know face-to-face interaction contributes to student learning, as well as the social and personal development that goes on in a residential experience."

John Seely Brown[12] "There are a growing number of misconceptions about the role of internet-based instruction that need to be addressed. It is no longer sufficient to simply learn how to learn from the internet and assume students will then be able to develop all the competencies needed for the 21st century. Traditional content is declining in importance as an educational goal as the complexity of problems increase in this century. "Wicked problems" (such as poverty)—where the important answers slip out from under you when you apply traditional reductionism—require a whole new holistic way of thinking. Preparing young people to grasp these problems requires a systems-level understanding of "ecosystems" where each component is inherently interdependent on many others. Serious learning of this type only happens in multidisciplinary study groups and studios, not in lecture halls. Learning the kinds of motivations and "dispositions" needed to address these complex ecosystem problems cannot be "taught" but only "cultivated." As a result, life on campus in an immersive environment has never been more important. Learning how to develop intuitive understanding for and design of ecosystems is beyond internet delivery for the foreseeable future."

John Bourne[13] "Based on extensive experience in founding and running the Sloan Center for Online Education (SCOLE)—which now involves a collaboration among more than 1,200 universities globally—we have found that the most successful and widespread model for online learning today is quite different from what is often described in the media. Instead of involving very elaborate interactive software and expensive Hollywood-style video production quality available asynchronously on the internet, the most successful models now in use involve very low cost connectivity tools (e.g., Skype) and open source software and data sharing to provide both asynchronous and live interaction of global participants around a topic or challenge of widespread interest. This involves both simultaneous conversations and asynchronous discussions around the globe that often take place at different times in different time zones, even though synchronous discussions are not convenient for many of the participants. More often, asynchronous communication is used. Rich discussions from widely divergent perspectives around the globe are enabled in real time and typically enrich communications. The power of the E-learning environment is generated by the spontaneity and unpredictable conversations and occasional conflicts that develop over issues from participants in many parts of the world. The syllabus for globally-delivered courses often develops in unpredictable ways. It now appears that most universities are deploying online methods and have found the benefits to learners are substantial. All participants in a course often document their collective learning by jointly developing discussion forums or a shared wiki that is developed as the course progresses.

The spread of E-learning is now accelerating and will put additional pressure on traditional residential educational programs. In particular, traditional universities must now work harder to better focus their programs on ways to use the physical presence of faculty and students to do things that cannot be accomplished just as well with more convenient and inexpensive electronic methods.

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[12] ***John Seely Brown*** is a visiting scholar and advisor to the Provost at the University of Southern California**.** Previously, he was the Chief Scientist of Xerox Corporation and the director of its Palo Alto Research Center (PARC)—a position he held for nearly two decades. He is a cofounder of the Institute for Research on Learning (IRL) and a member of AAAS, the National Academy of Education, a Fellow of the American Association for Artificial Intelligence, and a Trustee of the MacArthur Foundation.

[13] ***John R. Bourne***, Provost, American Sentinel University, is a prominent innovator in distance learning. He established the Sloan Consortium (Sloan-C™) in 1996 with support from the Alfred P. Sloan Foundation and served as its executive director. He also founded the Journal of Asynchronous Learning Networks (JALN), serving as its editor-in-chief until early 2012. Bourne is a professor emeritus at Olin College, Babson College, and Vanderbilt University.

In the few examples I know of where the opposite approach of developing a highly sophisticated interactive software package to serve as an engaging "expert system" to enable learn-at-your-own-pace instruction with high quality video, these have proven to be more costly than expected with overall effectiveness that has been quite disappointing. Perhaps one day this high end approach will take hold, but I don't see it in the near future. The key learning construct is students learning together via discussions, both synchronous and asynchronous and working toward shared learning goals."

Debbie Chachra[14] "While it may be tempting to imagine that learning covers a broad spectrum of activities ranging from relatively simple skills training to more complex education, each of which may be learned independently, the reality is that the most effective learning takes place when both aspects are integrated and taught together. This is the essence of the educational philosophy of Olin College. We call our approach the 'do-learn' model in which both aspects occur simultaneously. It is based on the idea that students learn best when they attempt to do things first, then when they encounter difficulties, they investigate why it doesn't work. Of course, the process repeats many times as the students evolve in their understanding, which naturally occurs in context. This mimics the process of engineering, which is inherently iterative. As a result, the process of learning used at Olin is not well suited to parsing into 'training' that is separated from 'education.'

In addition, our learning objectives include attitudes, behaviors, and motivations that extend well beyond knowledge and include teamwork, empathy, communications, and relationship development. According to some futurists (e.g. Jamais Cascio, 2012), the value of these human-oriented skills is likely to increase in the 21st century. While an increasing range of skills and knowledge are becoming amenable to automation (e.g., travel agents being replaced by specialized search engines), human interactions, rooted as they are in empathy, communication, and nurturing, are unlikely to be replaced by automation in the foreseeable future. This suggests that these skills, historically the province of women ('pink-collar jobs'), will increase in value.

This raises the possibility that the very definition of education will change in the years ahead. In the past, education may have been measured in terms of employability and career success. However, in the future, success may have more to do with creating purpose, meaning, and happiness."

Cherry A. Murray[15] "The recent edX partnership between Harvard and MIT is motivated by a fundamental desire to develop a not-for-profit platform and to collaborate on conducting research on how blended learning models using a large scale online learning platform can enhance student learning. Harvard and MIT together will decide how to analyze and share the data and how best to explore the fundamental research and development questions. Eventually, we plan to make edX an open-source platform available to all universities and researchers.

The financial model for edX is quite different from that used for the recent private companies Udacity and Coursera that spun out from Stanford. Those companies are built on a for-profit model and were funded by private capital. By contrast, edX is funded by internal funds from within Harvard and MIT ($30 million from each institution).

I expect that in each model, we will find that a few high profile courses with superstar instructors and topics of wide interest will draw the large majority of internet traffic and users. This could result in a 'winner-take-all' competition that increases pressure on all universities to provide opportunities of very high quality or be overlooked in the educational marketplace.

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[14] ***Debbie Chachra*** is an Associate Professor of Materials Science at Olin College. Her research interests are in the undergraduate engineering experience and in biological materials. She also writes a column on engineering education for ASEE Prism magazine.

[15] ***Cherry A. Murray*** is the Dean of the School of Engineering and Applied Sciences at Harvard University where she also holds the John A. and Elizabeth S. Armstrong Professorship of Engineering and Applied Science and in addition, is a Professor of Physics. She is a member of the National Academy of Sciences, the American Academy of Arts and Sciences, and the National Academy of Engineering. Before her appointment at Harvard, she served in executive leadership positions at the Lawrence Livermore National Laboratory and at Bell Laboratories.

However, our motivation for undertaking edX is to learn how to better use online learning methods in combination with more traditional approaches to enhance the quality of residential education on our campuses. We do not believe that this new large scale online platform will displace the demand for residential undergraduate education since the need for improved teamwork, experiential learning, and peer-to-peer learning has never been greater."

Jim Plummer[16] **"**Stanford has been involved in distance learning for working professionals (MS degrees in Engineering) since the 1960s, and has offered a fully online MS degree in Engineering for more than a decade. Historically, the MS-level professional education has proven to be the "sweet spot" for online education at Stanford. Last year, Stanford began experimenting with different technologies to enhance on-campus education. In particular, Professor Daphne Kohler experimented with a "flipped classroom" approach in which students are responsible to learn the basic content material online outside of class time to enable the time spent in the classroom to be devoted to rich discussion, project-based learning, and other activities intended to enhance understanding. To prepare efficient online material for her courses, she developed a "chunking methodology" in which the material is broken into "chunks." Each chunk begins with a 5 - 10 minute video, followed by interactive options that allow the student to explore exercises and problems at their own pace in order to develop a level of personal mastery and confidence in the material. This approach has proven successful with students who now prefer this method of presentation to the standard lecture format.

Professor Sebastian Thrun announced a Stanford Computer Science course last fall available on the internet free of charge to anyone who may be interested. This generated a lot of interest and an enrollment of more than 100,000 students online. It was successfully offered, using the "chunking" methodology. The experiment has grown and now involves several additional university partners and a menu of 12 – 14 courses now available online in this format, with enrollments that vary between 10,000 and 150,000. In addition, two new companies have formed as a direct result of this experiment (Udacity and Coursera) intended to develop educational opportunity for the masses, with about $10 million in venture capital. Stanford is not in any long-term formal relationship with these companies since this is still an experiment.

The working professional is the primary market for this new online activity, as this has proven to be the most successful market in the past. Much of Stanford's effort in the current experiment will be aimed at this professional market rather than on campus undergraduate education, although the courses are obviously available on campus, too.

Regarding the long-term effect of this massive open online course approach, it isn't clear yet what the effect will be. It is likely that the overall costs of higher education are closely linked to the cost of faculty (and staff). For example, the student/faculty ratio may be a good gross measure of the cost. For an elite private university, the student/faculty ratio may be about 6:1 with a total sticker price of about $50,000/year/student. But for a large public university, the comparable student/faculty ratio may be closer to 15:1 with total price of about $20,000/year/student. For a large public community college, the student faculty ration may be closer to 30:1 with a total price of about $10,000/year/student. Now, it appears that a well-designed internet-based technology platform can increase the effective student/faculty ratio for the same quality, and possibly even improve the quality in some cases.

In the short-term, it is unlikely that this will result in much overall cost savings for elite universities. In those institutions, the savings in faculty time will likely be reinvested in improved teaching methods involving more coaching and mentoring of students on unstructured problems to improve understanding of the material. This is what the "blended" IT teaching strategy is all about. But at some large public universities and community colleges, it is possible that costs will eventually decrease if the efficiencies are

[16] ***James D. Plummer*** is the Frederick Emmons Terman Dean of the School of Engineering at Stanford University, where he also holds the John M. Fluke Professorship in Electrical Engineering. He is a member of the National Academy of Engineering and the American Academy of Arts and Sciences as well as a Fellow of the IEEE. He has received numerous national awards for his seminal research in electrical engineering and nanotechnology and has also won three teaching awards at Stanford University.

used to reduce costs rather than reinvest in further enhanced teaching quality (i.e., avoid deploying "blended" IT strategies).

In those subjects where creativity and innovation, research, teamwork and design are important, experiential learning and close faculty interaction is essential. In those cases, it is unlikely that internet-based learning will provide significant cost savings.

Regarding residential programs, it is unclear what the long-term effects will be. The value of immersive social environments for learning at the undergraduate and Ph.D. levels seems clear, and these areas will probably be least affected by internet-based learning advances. However, as internet strategies improve, this will put pressure on residential programs to demonstrate their added value."

Tony Wagner[17] "If Olin College intends to produce exemplary engineering innovators, then the learning environment should emphasize innovation through teamwork, mentoring, and individualized coaching, rather than heavy emphasis on traditional technical course content. The learning models that are prevalent in the fine arts, performing arts and even athletics may be more effective than those in applied science. Judgment of competence in innovative capacity and achievement will most likely require direct involvement of experienced faculty members, rather than software. However, digital technologies can provide excellent tools for developing digital portfolios of accomplishments that might enable a self-paced "merit badge" approach to developing true competence, with the help of mentoring and coaching from faculty members. Internet-based instruction may reduce costs of learning content knowledge, but probably will not soon reduce the cost of developing judgment and creativity."

Questions. There is no question that internet-based instruction is accelerating and expanding and that significant changes in higher education are on the horizon. However, it remains uncertain how these changes will evolve and what they will mean for a selective undergraduate institution like Olin College. The issues raised above illustrate some of the complexities and possibilities. To further explore this issue, we will discuss the following questions when the President's Council meets in the next few weeks.

1. Given that there are many kinds of knowledge and learning, in what ways will internet-based instruction change the quality and character of undergraduate education in engineering?

2. Will internet-based instruction ultimately reduce the cost of undergraduate education in engineering? If so, how?

3. Will widespread internet-based instruction affect the value proposition of residential undergraduate education in engineering?

[17] ***Dr. Tony Wagner*** is the first Innovation Education Fellow at the Technology & Entrepreneurship Center at Harvard University. Prior to this, he was the founder and co-director of the Change Leadership Group at the Harvard Graduate School of Education for more than a decade. Previously he served as a Senior Advisor to the Bill & Melinda Gates Foundation, a high school teacher, K-8 principal, university professor in teacher education, and founding executive director of Educators for Social Responsibility. He is a widely recognized author in educational reform.