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THE ONLINE CHALLENGE TO HIGHER EDUCATION

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The Online Challenge to Higher Education

The future of universities may depend on blending the strengths of online education and those of face-to-face education—for the benefit of both students and the nation.

National Academy of Engineering Presational Academy of Engineering President Charles Vest tells a story about the roles of people and computers. In 1997, IBM's Deep Blue computer beat chess master Garry Kasparov; since then, chess masters have also periodically beaten computers. But Vest notes that the combined team of a computer and chess master always beats either the computer or the chess master alone. This says much about the future of higher education, especially in the sciences.

The idea has been growing that universities will change dramatically, and perhaps largely fade away, under the spread of online education increasingly enabled by improvements in broadband Internet access and new mobile devices. Recent years have also seen advances in the science of learning that are enabling society and researchers to look at new education approaches. The accumulating evidence challenges the model that has long dominated higher education: the sage on the stage; that is, the lecture.

These two potential revolutions—online education and in the science of learning—are on parallel but unconnected tracks heading toward a fundamentally different system of higher education. They need to be linked to optimize both.

A key component of the emerging educational world is massive online open courses, popularly called MOOCs, a term just a few years old. Early MOOC providers were forprofit firms that saw opportunities to capture higher education markets. At the University of Phoenix, a leader in online education, total enrollment by 2012 was approximately 308,000. At Kaplan University, another major online provider, enrollment was 78,000. Universities have responded to this market threat. At Coursera, an initial university MOOC platform originating from science faculty at Stanford, 62 universities now offer at least one course, including 16 recently added from abroad. Coursera adopted a for-profit model and obtained venture funding. Udacity, another forprofit MOOC provider developed by Stanford faculty, re- cently announced a master's degree in computer science program, in conjunction with the Georgia Institute of Technology and AT&T.

Concerned about the implications of grafting a for-profit approach onto nonprofit institutions, the Massachusetts Institute of Technology (MIT), later joined by Harvard University, launched edX as a nonprofit educational venture, with $60 million in experimental funding from the two schools. The edX alliance now has 27 university members, including 6 leading universities in Asia. Each school is creating courses for its own use and the use of others. The plan has been to post the courses and make them available without charge, although charges are contemplated in the future for students seeking a certificate of course completion.

The first edX course, from MIT, was on computer and electronic circuit design, directly taken from MIT's introductory circuit design course. It initially drew some 154,000 participants worldwide. Other MOOC providers saw comparable initial numbers. No one had seen such numbers attending a single course. Most of these early viewers proved to be "shoppers," testing the buzz and content. Some 7,000 people eventually completed the edX course for a certificate. Even this number is breathtaking—60% more than MIT's undergraduate enrollment. edX, operating since 2012, recently counted its millionth student.

Online students proved to be self-assembling, assisting each other and organizing online and in-person discussion groups. edX has become the theater, staging the show with the participating universities developing the course content around evolving edX design standards. edX is developing and offering the platform and assessment software, serving as the common technical support mechanism. Developing quality online courses, assuming they are not mere videos of lectures, is much more expensive than developing a physical classroom course. Although the courses so far are free and universally available online, schools offering MOOCs will need to charge for completion certificates to cover development. However, the MOOC business model is by no means clear. Schools are starting to see that alongside their established university, they may have to form a “Pixar” branch.

MOOCs and educational reform

Many politicians in the United States seem to feel that MOOCs represent a kind of “new magic”: online higher education for free. Although never explicitly stated this way, conservative politicians seem to be hoping that for-profit online higher education can finally rid the republic of those pesky, left-wing universities. Progressive politicians, on the other hand, seem to be hoping MOOCs will end what they view as outrageous university tuition rates, driving tuition through the floor and making higher education more accessible than ever before.

This desire for lower costs can be seen in Florida, where the governor issued a challenge, and 23 state colleges agreed to offer the option of a $10,000 bachelor’s degree. California, which has been systematically slashing state support for higher education, recently passed legislation requiring state universities to give credit for online courses where there are not enough physical classroom seats for students. The pressure to cede education to online courses is growing as states cut funding for higher education to pay for the growth of Medicaid expenditures and prisons. Because some 72% of U.S. higher education is provided by state-funded higher education systems, this is powerful pressure.

Given these pressures, what will happen to the campus— to residential higher education? Although MOOCs will affect all types of higher education, from community colleges to private colleges to the several tiers of regional state universities to for-profit education providers, we focus here on the first tier of research universities, public and private, and particularly on education in science, technology, engineering, and mathematics (the STEM fields).

The research university has evolved over the past 150 years or so into the most important home for scientific advancement; it is the base system for global knowledge. The research university is a comparatively new creation in the United States, modeled in the late 19th century on the German university and coming into its own through the massive federal investments in R&D during World War II and the subsequent Cold War. The brilliance of this model was in combining research and education, so learning became hands-on, with research and learning being mutually reinforcing and learning continuous. This learning-by-doing model, although remarkably effective, has also contributed to the high cost of undergraduate science education, as students need increasingly expensive labs.

The entry of the lab into science education was a creation of mid-19th century reformers such as William Barton Rogers, who helped shift natural science away from the lecture model and its accompanying recitation and memorization. This critical education reform was followed by the introduction of the seminar in the first part of the 20th century. Education philanthropist Edward Harkness, a Standard Oil heir who felt that middle-range students (such as himself) were left out of a system that focused only on students at the top and bottom of classes, funded Phillips Exeter Academy faculty to study Oxford University and Cambridge University models for education ideas. Finding that the remarkable one-on-one tutorial system at those schools was prohibitively expensive, the Phillips Exeter faculty created the seminar of 12 or so students around an oval “Harkness table” in the 1930s to bring all participating students into the common discourse. The model spread to the Ivy League and widely to U.S. universities for upper-level courses.

MOOCs are potentially an even more transformative revolution. They may be a particularly interesting new tool for STEM education. This is because problem-solving in these fields may fit more readily into online courses than does the discourse emphasis in humanities or social science courses. Online learning can enable dynamic visualization of data and the ability to interact with that data, allowing the ability to identify new data patterns and influencing factors. It opens new ways for mapping the content and core ideas of a field, with new possibilities for the representation of both information and knowledge. And it can be great tool for real-time assessment of content acquisition and knowledge transfer and application, with the ability to improve reinforcement of content.

> If society can get the model right, there is an opportunity for worldwide availability of courses.

Even as online education advances, vital education components will remain face-to-face at least for some time to come. Developing expertise through oral expression and presentations will remain especially critical. Online education simply cannot handle these aspects of learning very well so far. Conventional education methods can also effectively promote written analysis. Machine evaluation of written papers is improving, and edX, for example, has a team working on this technology. But although software can capture key words and rubrics supplied by faculty (what might be called established concepts), it will not be good at be called established concepts), it will not be good at recognizing out-of-the-box new ideas or evaluating ideas with fresh approaches. For a very long time to come, writing will require human assessment, except for more straightforward assignments.

Conventional education will also remain vital in research, where online capabilities can be limiting. Performing research is central to learning by doing in science; indeed, it is what scientists do. Although computer simulations and modeling can capture elements of how to perform research, in many fields the student ultimately needs to be at a lab bench or in the field, interacting with a research team for project-based learning. Online features can enhance research. For example, data visualization and display and computer simulations can be critical tools, and MIT has an "iLab" for high-school science students, where they can run real experiments online from any location on real MIT equipment. But there is no getting around the reality that research in many fields requires critical face-to-face dynamics and interactions with the natural world that will be hard to replace.

Blending for success

In the end, then, MOOCs may change everything, but they will not necessarily kill everything. Indeed, at least in the near term, the most effective education will combine online and face-to-face approaches into "blended learning" that captures the best of both worlds.

In this scenario, online education will continue to evolve. In some ways, it will become better at doing some of the jobs that are the hallmarks of conventional education. For example, with growing broadband capability, it will be possible to further build online discussion groups, and the videos will be increasingly be able to use high-definition capability for improved realism. Machine writing evaluation will get better. Even now, for shorter papers, in which software can increasingly evaluate key word use, rubrics, and core concepts, MIT's machine grading software matches the score of a human grader as accurately as a second human grader 85% of the time. And as noted, research can be complemented by online simulation and modeling and can offer online access to lab equipment and the ability to run experiments online.

There is a larger point, as well. "Face-to-face" conventionally has implied physical proximity, but there are significant learning areas where, as technology continues to improve, face-to-face is transforming into "person-to-person," where virtual personal connections are online. Personalized education is not likely to remain the sole province of face-to-face education.

So even as online and face-to-face approaches manage a certain détente, online is likely to become an ever more disruptive force. It is now well accepted that new firms embracing new technologies can disrupt and eventually displace legacy firms.

Clayton Christensen, the business professor who developed this field, argues that when nonprofit higher education was a service-only sector, it was protected. Its service model had long since absorbed book technology as its one technology base, already a mature sector after five centuries of development. It had been successful in evading any significant new technology component, facing only modest incursions from the private-sector online education system, which had been slowly evolving. When a point was reached where online entry could scale, with significant broadband access and smartphone entry, the way was open for a new technology component to enter higher education. It was the arrival of this new technology that created the possibility of disruptive displacement for the existing higher education system.

Christenson proposes an analogy: Online is the steamship. Early steam engines were very inefficient, requiring great volumes of wood or coal. They could not power a ship across an ocean, but they found a niche market, starting out on rivers. Steam engines, although initially inefficient, had a compelling advantage; they could move steadily upriver into current and wind, stopping when necessary to refuel. As the engines became more reliable and efficient, they became suitable for longer trips. Shipmakers then developed a hybrid technology that incorporated steam engines into sailing ships. Sidewheels were replaced by more efficient screw propellers, and the development of steel hulls made it possible to build larger ships that could carry more fuel. Sails were eventually eliminated, and the hybrid technology was replaced by steam-only vessels. Will this be the higher education story? Will blended learning (the hybrid model) eventually fade and be displaced by an online steamship? Will universities go the way of sailing ships?

Even as it proves disruptive, however, online education will continue to depend on conventional education, especially universities, for some time to come. The fundamental reason is that if universities were to disappear, the institutional source for course content would collapse over time. Universities are also research engines as well as teaching and learning centers; at least in science, that research side has a separate funding system that could be maintained, apart from education tuition (although tuition revenues provide research subsidies, because universities do not fully recover their indirect costs from the federal government). In a knowledge indirect costs from the federal government). In a knowledge economy, there is no substitute for universities, which are literally innovation systems that are critical for societal growth. With industry research ever more focused on incremental advances in later development stages, the breakthrough stage increasingly is a university role, using federal science research funds. University research, by proving a foundation for learning by doing, is also central to science education.

Although there is no real replacement for many research university functions, it is possible that the university in its present form will survive only if it significantly reforms its face-to-face learning model. Its age-old primary delivery tool, the lecture, is no longer the optimal model. A head-to-head competition between a live talking head in a classroom and an online presentation with assessment and interactive features built in is not a winning proposition in the long term for the classroom lecture.

So the online education revolution is here. Universities can take an ostrich approach and allow continuing and systematic market incursions from for-profit online operators. Or they can figure out the new online tools for learning and reform their face-to-face course offerings. The reality is that universities cannot ignore the new disruptive online education phenomena.

In the beginning

The MOOC movement to date has largely been led by creative computer scientists, not learning experts. But the parallel revolution evolving now in the science of learning will need to be incorporated into online education and the blended learning models that universities need to develop.

A recent report from the National Academies called *Discipline-Based Education Research: Understanding and Improving Learning in Undergraduate Science and Engineering* provides a good summary of where things now stand. In essence, undergraduates in science and engineering face learning challenges, for example, in conceptual understanding, problem solving, and visual representation. In conceptual understanding, students often harbor incorrect ideas in every discipline about fundamental concepts, having particular difficulties with concepts at both large and small temporal and spatial scales. In problem solving, students can be distracted by the superficial aspects of a problem, such as objects in the problem or the context of the problem, whereas experts know to focus on underlying principles. In visual representation, students often struggle to interpret models, graphs, or simulations, which are key to grasping scientific concepts.

There is a solid body of research that shows that instructional strategies can overcome such challenges. In teaching conceptual change, it is possible to use bridging analogies that provide links from a student's erroneous understanding to a correct understanding, and such techniques can be included, for example, in interactive demonstrations. Problem-solving skills can be developed using open-ended problems, carefully structuring the learning with prompts and encouraging peer-to-peer, or near-peer, interactions. Concerning representations and spatial ability, the use of multiple forms of representations can improve students' grasp and facility. The effectiveness of computer animations and simulations is not yet fully understood, but they may well play a role. The evidence clearly shows that student-centered collaborative instructional strategies can help students' learning and retention.

The Academies' report does not say that lectures are inherently ineffective, but recommends framing them within a range of instructional approaches. Similarly, online technologies alone do not improve learning outcomes. Outcomes depend on how the technology is used and placed in a larger learning context. So online learning occurs in a larger context of science learning; it alone is not a full solution, and the findings in each of the areas can be applied to inform both online and blended learning.

Research on sequencing learning can also inform online courses. For example, there has been much discussion lately in education circles of "the flipped classroom." But educators may be flipping it backward. Putting lectures online and asking students to view them in advance of class before encountering problem solving may be less likely to advance robust learning. Some research at Stanford suggests that encountering the problem should proceed "telling," because students may be more efficient at absorbing and applying the explanation if they see the content in the context of problem solving. Students who confront practical problems before being provided with the explanation appear to be better at transferring their learning to other contexts. The blend of classroom and online may improve learning if they are complementary and informed by learning science research. If online is to make a serious contribution to education, the systematic application of learning science appears crucial.

These examples begin to reveal the outlines of a blended learning model. The model will require an optimal division of tasks that reflects the strengths of each environment. As Sanjay Sarma, director of MITx (MIT's online course development entity), has stated, "this new [online] tool might streamline first order learning and free us up to enrich second order learning." He proposes that online can absorb much of the information and content-conveyance tasks (first-order learning), and the face-to-face classroom can focus on the understanding and conceptual depth of second-order learning. The online element in the blended model can integrate the lecture model, but space it into shorter, more absorbable segments, reinforcing each segment with the interactive features at which online excels, such as visual data displays, animations, and problem simulations. Online will take advantage of emerging continuous assessment software that will frequently test student understanding and reinforce concepts and practices that were not adequately understood.

The face-to-face classroom will become a space for more seminar-like discussion sessions where students can learn to express and organize expertise, engage in participatory lab work and demonstrations, and frame overall problems that they then will mine the online resources to help resolve. Apprenticeship learning by doing and learning progression approaches, using teachers as mentors, also become possibilities. Basic short papers to test the students' information acquisition can move online; conceptual papers to demonstrate creative thinking and problem solving could receive more attention from faculty members freed from lecturing. Problems initially could be framed in the classroom, followed by supporting online material, so that the classroom is flipped in the most productive direction.

The science of learning will advance through analyses of massive data from students learning online and will inform both virtual and physical settings. A major professional development effort for faculty will be essential to ensure effective learning and teaching in new online, blended, and traditional environments. Research on both the science of learning and faculty development will be key to education reforms.

Worldwide online education

If society can get the model right, there is an opportunity for

worldwide availability of courses. If you can get to a smartphone (and this technology is increasingly pervasive even in significant parts of the developing world), you can get access to global knowledge. Many low-income learners in undeveloped places will now be able to access the world's great education institutions. But this does not have to be a monopoly of the developed world. There is important specialized knowledge in the emerging and developing world that can now be contributed that was previously far less accessible.

In this global vision, a wide range of institutional types will be able to collaborate, bringing their assets and strengths able to collaborate, bringing their assets and strengths together to create innovative learning environments. edX online science course material, for example, is being used in blended courses at San Jose State in the California system. Similar alliances are being considered with community colleges, where the teaching expertise in reaching a diverse student body will inform further development of the edX platform. The new MOOC consortia have enlisted international partners, so these alliance options can go global.

The expansion of reach through online offerings means that a university's prior assumptions about the size of its student body can dramatically shift. MIT is discovering that it does not have to consist of 10,000 students on its campus, largely between the ages of 18 and 28. Its student body can be worldwide and much larger and embrace a wide age demographic.

> To raise the online technology bar, universities will need to consider supplementing their traditional faculties with online development experts.

From credentials to speedier degrees

What will students get for completing an online course? There are important questions about written and oral expression that must be worked through in accepting MOOCs for course credit. Issuing students credentials or certificates for completing many online courses, as opposed to giving them a full-credit course grade, may be a reasonable scenario. The certificates need not be a second class of education, just a different kind of education. Employers, for example, may well be interested in systems where students obtain "stacks" of online credentials to demonstrate skills or content understanding. Online courses can be broken up into topical modules and resorted and restacked to fit different kinds of credentials. In 2010, U.S. education institutions, led by community colleges, already granted over 1 million certificates annually in a range of specific semiprofessional programs—the fastest-growing form of higher education. The certificates are increasingly recognized as valuable by employers offering pay differentials for them. Employers are also starting to focus on hiring based on levels of core skills, such as applied math, critical listening, close observation, information compilation, and written expression, matched to job requirements. Many of these skills may not be reflected in a traditional college education. The flexibility of online credentialing may better suit this trend toward lifelong skills assessment.

Beyond credentialing, online learning may help some students complete college degrees. Colleges and universities may get to the point of offering their introductory courses online. In that scenario, entering students, by taking online courses during summers or on their own time or in high school, will come to college with a year or more of introductory courses completed. Perhaps college could be three or even two years, correspondingly cutting costs for students. The later years of college could focus more on discussion-based seminars or on more advanced research or writing projects, with more student-faculty interaction— the parts of the learning equation that online does not yet manage well.

How would colleges and universities manage the economics of this shift? They would still have to maintain their campus plant. But if colleges became two- or three-year institutions, they could increase their student throughput and retain their plants. MIT President Rafael Reif, who personally led the creation of the edX and MITx models, has suggested that colleges could change their admissions practices if students complete a first year of introductory courses online. Colleges will know how students are performing on their own courses, and this might prove a more direct system for judging admissions than SATs or high-school AP scores.

Online learning may also play a role well beyond the college years. Indeed, a critically important role for online education may be for lifelong learning. After a person has acquired expression skills through a college education, online courses may fill a great need. Adult learning is increasingly based on providing content and information, an online strength. This approach would be well suited to helping adults update their skills to stay current with employment demands. MIT's Reif has suggested that perhaps in the future when people apply to college, they will apply for a lifelong content learning opportunity.

Evolving business model

The entry of MOOCs into higher education is in its infancy. Because their potential is only starting to be understood, the business model is not clear. But there are suggestions that several features of MOOCs will have to be addressed if sound business models are to evolve.

First, MOOCs will require expensive up-front development. To offer quality courses with interactive features means development investments; to simply offer videos of existing lectures completely underuses the medium and its interactive and assessment potential. To raise the online technology bar, universities (or consortia of universities) will need to consider supplementing their traditional faculties with online development experts. And there will be a need for development experts. And there will be a need for expenditures to develop standard “platform” software features that can snap in to serve a menu of courses, reduce their costs, and improve performance (for example, through assessment). But though significant, the up-front costs potentially can be dispersed over a much wider group of students, enabling a significantly lower cost per course per student. Working out a sound pricing model will be a work in progress for some time to come.

At this time, MOOC courses can be freely available. If a student wants a certificate, assessment will be needed, and a modest charge can be imposed depending on the course population; but at what level? Georgia Tech’s collaboration with Udacity for an online master’s degree in computer science suggests how MOOC pricing options may evolve. Georgia Tech will charge students seeking credit for its respected computer-science program a price closer to that of a community college: approximately $134 per credit, as compared with the normal rates at Georgia Tech of $472 per credit for in-state students and $1,139 per credit for out-of-state students. The program is expected to take most students three years to complete and cost around $7,000. Income will be split 60/40 between Georgia Tech and Udacity. Clearly, differential pricing within an institution is now being introduced for online versus face-to-face (or blended) courses. Will there be popular blockbuster courses that (like blockbuster Broadway shows) can charge a premium? If more of the teaching load is picked up online, will faculty size decline; and if so, how will research universities cover the range of expertise they need to offer? Regardless, universities (and certainly the for-profits) will clearly need to recoup their development costs. Otherwise, this revolution will be stillborn.

The pricing models for nonprofit MOOC providers could prove advantageous for experimentation, because prompt profit recovery does not have to be built in, but will nonprofits be able to keep up with for-profits in incorporating technology advances? edX has recently announced an “open source” approach for its software platforms, posting its code and inviting the software community to contribute improvements in a “commons” development model. Textbook publishers are entering online education as well, creating textbooks that will increasingly be packed with online features, and publishers may also collaborate with MOOC consortia.

Universities may need to use MOOCs to cross-subsidize their campus courses, traditional and blended. As they offer improved face-to-face learning, under pressure to reform as the low-cost standard lecture is displaced by MOOCs, universities may have to move to a more expensive model with more intense faculty mentoring and seminars. Can universities recoup these costs against their MOOC offerings? As they do so, they will be going up against a tradition that online offerings should be free. They will also be going up against for-profits that will not necessarily face carrying costs for big campuses and research facilities. And there are the additional problems of what to charge if a university offers lifelong learning access? Or, if one university develops a course, and another uses it in a blended model, what does the first university charge the second? edX has two cost recovery approaches for its university partners: lower-cost "self service," in which a school or its faculty members develops an online course (to edX standards) but uses the edX system for its distribution; and "edX-supported," in which edX charges more as a course design partner, contributing technology know-how to course construction, as well as handling the online distribution.

Adding to the economic complexity are unresolved intellectual property issues. The Bayh-Dole Act has leveraged the translation of innovative research but is not applicable to the world of MOOCs. Textbook royalties have motivated some faculty. How will university or faculty ownership of MOOCs affect tomorrow's university and professional identities?

Overall, a very different business model for online verses face-to-face higher education is likely for a very different cost structure. While efforts continue apace to start MOOCs, its backers, and society at large, are shooting in the dark on the business model. It could be both interesting and disruptive. But there is the possibility of significantly lowering student costs if part of their education can shift online.

Understanding the risks

The bottom line appears to be that universities that are largely lecture-based with a limited research base may be in for a rough ride as they try to shift to new models for online and face-to-face education. Increased student throughput offers one ray of hope, but some schools may have difficulties in attracting sufficient students to be able to increase throughput. The point here is that online-only education is not perfect. There are limits in its ability to facilitate learning, but it is going to be pretty good, particularly in providing and reinforcing content and information. If lower-cost online courses with interactive and assessment technical features go head-to-head in competition with less learning-efficient face-to-face lectures, online wins. And the lifelong learning potentials for online education will provide an extra advantage.

Universities are starting to recognize what they need to do: develop a new blended model, with a new, more dynamic role for faculty. Face-to-face learning will survive only if it uses the unique strengths that it can muster in expression, written analysis, and performing learning-by-doing research. Asking higher education, which has been historically adverse to innovation, to pursue two simultaneous major education reforms—online and blended—is asking a lot. But it may over time prove the only move.

There is a risk here, of course. The nation may develop a double standard for higher education. The upper middle class may be able to afford a blended model, but the less well-to-do may have to make do with a much cheaper online-only system. Because blended, if done right, offers better learning potential at least at this time, what will be the societal effects?

Indeed, there are a host of questions to be answered. Society and the research community have much to learn about learning—in classrooms, online, and in blended learning settings. Online education presents an opportunity to significantly reform the quality of learning in higher education. If meaningful learning analytics can be applied to the growing ocean of online data, the nation could undertake learning research at a scale previously unavailable.

The good news is that it is becoming possible to tackle long-standing learning science questions: Does the effectiveness of instructional practices vary for students of different ages and groups? Can the transfer of learning across courses be enhanced? Are there optimal ways to structure learning over time or multiple courses? How do noncognitive aspects of learning, including motivation and social learning features, influence student success? Online assessment, if done properly, can reveal much about learning in ways that could drive educational reforms in online and face-to-face education. To achieve such goals, and to improve both online and face-to-face education, it will be necessary to systematically apply what is now known and what is learned in the future about learning science.

If all goes well, the nation will embrace a system in which online education does what it is good at (providing content and information, enhancing data visualization, and improving critical assessment), and face-to-face education does what it is good at (fostering discourse and argumentation, mentoring, training students for research, and making conceptual leaps). It will be this human-online symbiosis—the right blend of students, teachers, and teams with online capabilities— that will catalyze a new generation of science learning. To return to the chess metaphor, to achieve optimal learning, it will be Deep Blue and Garry Kasparov working together toward a common goal.

Recommended reading

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