EXECUTIVE OFFICE OF THE PRESIDENT
PRESIDENT'S COUNCIL OF ADVISORS ON SCIENCE AND TECHNOLOGY
WASHINGTON, D.C. 20502

December 2013

Dear Mr. President,

When the President's Council of Advisors on Science and Technology (PCAST) spoke with you after your reelection last November, you expressed concern about barriers to economic mobility. These barriers stem from many factors, such as widening income disparity and rising healthcare costs – all have contributed to a growing inequality of opportunity. Prominent among these contributing factors are the rise in the cost of higher education, a concern that many graduates may not be well-prepared for future workplaces, and a growing need for lifelong learning to maintain and upgrade one's skills and competencies.

Access to higher education is a pathway to success in modern society. Yet, over the past decade, published tuition and fees at public, four-year colleges have risen 5.1% per year faster than the rate of inflation.[1] In the previous two decades, the rate of increase was lower, but still 3.8% above inflation.[2] The data on what students actually pay are even more disturbing. The net price (tuition minus financial aid) at public, four-year colleges has risen 6.7% per year beyond inflation over the past decade.[3] If this trend continues, it will shake the foundation of the American Dream, putting a college education out of reach for many young people in America, especially for middle-class families who have difficulty qualifying for financial aid. And those who cannot afford higher education will have limited opportunities to succeed in a global economy based on knowledge and innovation. The United States must not only make a college education both more affordable and more effective, but also provide skills to many in the workforce via learning opportunities that are more flexible than the traditional four-year model of residentially-based higher education.

Recent advances in technology expand potential approaches to address these challenges. Novel uses of information technology in higher education offer the possibility of (1) decreasing educational costs, (2) increasing overall educational quality, (3) adapting the educational experience to individual students' learning styles, and (4) enhancing workforce preparation and lifelong learning. These possibilities have yet to be realized, but they have provoked considerable interest.

This is the first in a series of memos that PCAST plans to prepare on the topic of the role of technology in education. This memo addresses the specific case of MOOCs: massive open online courses.[4] MOOCs have received much public attention, partly driven by a handful of

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[1] Tuition and fees at private, nonprofit, four-year colleges have risen at an average annual rate of 2.3% above inflation since 2002-2003. Tuition and fees at public, two-year colleges have risen 3.9% above inflation for this same period. "Trends in College Pricing 2013." *College Board*. 2013. Web. 6 Dec. 2013. <http://trends.collegeboard.org/college-pricing>.

[2] Ibid.

[3] Ibid.

[4] PCAST developed the ideas presented here through its own discussions beginning in late 2012 and through consultation with several experts at meetings, during conference calls, and, in particular, at a workshop on August 29, 2013. Key contributors include Randall Bass (Georgetown University), Lori Breslow (Massachusetts Institute of

experimental courses that attracted 100,000 or more students.[5] In response, hundreds of colleges and universities across the United States are now studying or experimenting with MOOCs and other, related educational technologies.[6] Multiple platforms for offering MOOCs have emerged, including a for-profit company, Coursera, that is developing MOOCs with 107 partner colleges and universities;[7] a nonprofit organization, edX, that is affiliated with a smaller number of university partners (including some that are also partners with Coursera); and a for-profit company, Udacity, that is developing MOOCs largely outside of formal relationships with colleges and universities.

It is important to keep in mind that neither the massive, nor the open, nor the online nature of MOOCs is really new.[8] In the first half of the 20th century, millions of Americans enrolled in correspondence courses as an alternative to formal study at colleges and universities.[9] Such efforts shifted as information technology progressed, first through radio broadcasts of courses produced by many universities in the 1920s and 1930s, and then through teaching using motion pictures and television.[10] The United Kingdom's Open University began to offer fully certified college courses for credit over television in 1971.[11] Stanford University has used technology to teach engineering courses for the employees of sponsoring companies since 1969.[12] More recently, Massachusetts Institute of Technology (MIT), Yale University, and the University of California at Berkeley have offered dozens of full, semester-length courses – lectures, readings, problem sets and other assignments – online, free of charge, without examinations or certification. In this context, one might see MOOCs as merely a natural progression of distance learning.

Technology), Mung Chiang (Princeton University), Zvi Galil (Georgia Institute of Technology), Kevin Guthrie (ITHAKA), John Kolb (Rensselaer Polytechnic Institute), Robert Lue (Harvard University), Andrea Nixon (Carleton College), Rahim Rajan (Bill & Melinda Gates Foundation), and Candace Thille (Stanford University). PCAST is both grateful for these inputs and responsible for the conclusions presented here.

5 For example, 160,000 students from over 190 countries registered for Stanford University's free online course on artificial intelligence in the Fall of 2011. See Firth, Simon. "Stanford Engineering's New Online Courses: Hugely Popular and Bursting with Activity." *Stanford Engineering.* Stanford University. 17 Oct. 2011. Web. 9 Dec. 2013. <https://engineering.stanford.edu/news/stanford-engineering-new-online-classes-hugely-popular-and-bursting-activity>. See also Waldrop, Mitchell. "Campus 2.0." *Nature.* p.160 vol. 495. 14 Mar. 2013. Web. 9 Dec. 2013. <http://www.nature.com/polopoly_fs/1.12590!/menu/main/topColumns/topLeftColumn/pdf/495160a.pdf>.

6 MOOCs have helped to expand appreciation for online education among educators. For example, a recent study reported that 69.1% of chief academic leaders in higher education report that online education is critical to their long-term strategy. See Allen, Elaine, and Jeff Seaman. "Changing Course: Ten Years of Tracking Online Education in the United States." *Babson Survey Research Group.* Jan 2013. Web. 6 Dec. 2013. <http://www.onlinelearningsurvey.com/reports/changingcourse.pdf>.

7 "A Triple Milestone: 107 Partners, 532 Courses, 5.2 Million Students and Counting!" *Coursera Blog*. Coursera. 23 Oct. 2013. Web. 6 Dec. 2013. <http://blog.coursera.org/post/64907189712/a-triple-milestone-107-partners-532-courses-5-2>.

8 For a more complete discussion, See: Golden, Claudia, and Lawrence F. Katz. *The Race Between Education and Technology*. Harvard University Press. 2010. Print.

9 Kett, Joseph F. *Pursuit of Knowledge Under Difficulties: From Self-Improvement to Adult Education in America.* 1996. p. 236-238. Print.

10 Cuban, L. (1986). *Teachers and Machines: The Classroom Use of Technology Since 1920*. New York: Teachers College Press.

11 "History of the OU." *The Open University.* Web. 2 Dec. 2013. <http://www.open.ac.uk/about/main/the-ou-explained/history-the-ou>.

12 In 1969 the Stanford Instructional Television Network began using microwave television to reach off-campus students. "About Stanford Online." *Stanford University.* Web. 2 Dec. 2013. <http://online.stanford.edu/about/history>.

But MOOCs offer something different from radio, video, and even Internet courses of the past. Improvements in bandwidth and software innovations have enabled enormous improvement in the speed and quality of communication among large numbers of students and between students and teachers. The new MOOC technologies should allow teachers to measure student comprehension in real time and adjust the material presented to students to achieve higher levels of competency. These new educational technologies have the potential to allow teachers and schools to move away from measuring student progress merely as the number of hours spent in a classroom, and toward a system that measures outcomes – learning and competency – almost continuously and in real time. Better measurement of learning and subject matter mastery will allow teachers, their schools, and MOOC platform providers to evolve rapidly toward the pedagogical methods that are most effective. Although the new technologies introduced by MOOCs are still in their infancy, and many questions and challenges remain, we believe that they hold the possibility of transforming education at all levels by providing better metrics for educational outcomes, and better alignment of incentives for innovation in pedagogy.

In addition to the potential improvements in learning and teaching that the real-time interactivity of MOOC platforms may provide, the new technologies also permit teaching at scale – connecting large numbers of students to an outstanding teacher, and to each other. This scalability suggests the potential both to increase access to higher education and to reduce its cost.

The first-generation MOOCs introduced in the past two years have been massive, open (that is, free of charge), and online, and most have been full-length courses rather than smaller units of learning. But the fundamental innovations that the MOOC platforms allow – real-time connectivity at scale, feedback, assessment, and continuous improvement – do not require that education be massive or open or divided into the traditional form of semester length courses.[13] There can be fruitful variation on each of these themes, as has begun to be observed.

The production and implementation of online courses, especially when student learning is being assessed and material adjusted to the student's needs, is by no means costless. Consequently, what seems to be evolving is a varied set of online offerings using the MOOC platforms and technologies, some of them free, some of them for pay, with the level of tuition increasing with amount of services rendered. In the pattern that seems to be emerging, courses would be free to students who merely participate and may receive a certificate verifying participation. But to the extent that a student's individual performance is assessed and competency is certified, it is likely that providers will charge tuition. At the extreme end, students will enroll in courses that bear credit towards a degree at the educational institution providing the course, or at other institutions accepting the credit. Whether, as the market matures, such courses will be offered at a substantial discount from courses offered "offline" on physical campuses remains to be seen. But the potential for access not just to specific courses but also to fully accredited undergraduate and advanced degrees is clear and present.

Some educational institutions are already moving to embrace online degree programs over MOOC-type platforms. For example, Georgia Institute of Technology (Georgia Tech), AT&T, and Udacity recently announced a computer-science master's degree program mounted on one of

[13] Participants in PCAST's August 29, 2013 workshop expanded on these issues, drawing from their experiences at multiple institutions.

the new platforms.[14] Slated to begin in January 2014, this program allows students a variety of options. Those who wish to pursue the full degree pay a tuition fee of $6,600, well below the roughly $47,000 tuition charged by Georgia Tech for two years in pursuit of the equivalent degree on campus. Those who wish to take a single course or two, which potentially might be recognized for credit at other institutions, pay a much smaller fee. And those who simply want to take the course without credit may do so for free. Enrollment in the degree program will be initially limited to 600 students who must apply and be admitted, but the goal is to reach annual enrollments of 10,000 degree-bound students within about three years.

One should be mindful that the use of MOOC platforms is still at a very early stage, and, as with any new technology, it is likely that failed experiments will outnumber successful ones. A high-profile experiment at San Jose State University, in cooperation with Udacity, offered introductory math and statistics courses in MOOC format for college credit at a very low cost ($150 per course).[15] Disappointingly, the pass rates for these courses were well below those achieved in the traditional, instructor-led versions of the same courses, and the program was put on hold. With so much experimentation taking place, such results are to be expected; the important point is that the MOOC technology will provide the data on outcomes needed to evaluate what is successful and what is not, allowing further investments and further refinements to be based on data rather than anecdotes.[16]

One possible trajectory for the MOOC technology would be to reduce the cost of education simply by economizing on the use of teachers, using computerized feedback to support a course rather than online or offline personal guidance by a faculty member or teaching assistant. The potential for displacing academic labor is already causing concern in some quarters.[17] Indeed, opposition by faculties at some institutions may become a significant obstacle to the widespread adoption of MOOC technologies.

A related concern is that as MOOCs reduce costs, certain aspects of a live classroom experience, such as the capacity of a teacher to inspire and motivate students, may be attenuated or lost. And, of course, an education earned entirely online would deprive students of many of the benefits of residentially-based education such as opportunities to learn teamwork and leadership through extracurricular activities, and personal counseling, among others. On the other hand, advocates would argue that new technologies permit improvements in quality such as the development of more specific measures of student comprehension and competency, which are likely to improve upon traditional mid-term and final examinations. And teacher effectiveness

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[14] Zvi Galil, dean of Georgia Tech's College of Computing, discussed the program at PCAST's August 29, 2013 workshop. All three of these partners are investing in the launch of the program; AT&T represents the kind of organization whose employees would benefit from participating in such a program. Georgia Tech already offers conventional online master's degree programs.

[15] Harris, Pat. "SJSU and Udacity Partnership." *SJSU Today*. San Jose State University. 15 Jan. 2013. Web. 2 Dec. 2013. <http://blogs.sjsu.edu/today/2013/sjsu-and-udacity-partnership/>.

[16] An NSF-supported study has already been published, analyzing the reasons for the poor results obtained initially in the San Jose State-Udacity courses. See Collins, Elaine D. "Preliminary Summary SJSU+ Augmented Online Learning Environment Pilot Project." *The Research and Planning Group for California Community Colleges.* Sept. 2013. Web. 9 Dec. 2013. <http://www.sjsu.edu/chemistry/People/Faculty/Collins_Research_Page/AOLE%20Report%20-September%2010%202013%20final.pdf>.

[17] This concern reflects the potential productivity gain from a given faculty member reaching more students than in a classroom-delivered course. Early experience with MOOCs, including planning at Georgia Tech referenced above, also shows that the trend is for more professionals of different kinds to support both the production and delivery of online education to very large numbers of students.

could potentially be judged on these measures of student comprehension and competency rather than test scores or student satisfaction. Moreover, real-time measurement of achievement would allow for truly adaptive teaching platforms that customize content based on student performance. A key question is whether MOOCs will incorporate what is already known about how people learn into course structure and design. For example, Carnegie Mellon University's Open Learning Initiative (OLI) has built in "learning science" and demonstrated effective results; its interdisciplinary approach has differentiated OLI.[18] One concern is that there may be more emphasis on the technology of the course and less attention on incorporating the lessons of learning science.

A deeper concern, raised especially but not exclusively among faculty in the humanities, is that online courses may not be capable of inculcating in students the kind of independent critical thinking that they are encouraged to develop through sustained classroom argumentation and writing papers. A related concern of some scientists is that online education may not foster in students the kind of deep intuition for a subject that leads to significant innovation in science and technology. Online courses, with interactive real-time feedback, may be ideally situated to assess the mastery of content, but it is not yet clear that they can successfully assess the ability of students to express themselves clearly and formulate independent, original ideas and arguments, tasks that by their nature may not scale. Advocates of online education hold out "peer grading" of written assignments as a possible solution, but higher-education media and blogs show that many teachers remain skeptical.

After only two years of practical experience with MOOCs and related technologies, it is too early to tell whether substantial gains in the quality of instruction, access, achievement, and cost will be realized. But there is no question that the new technologies offer the potential for expanding access for millions of Americans, not only to college degrees, but to a wide range of effective and low-cost training modules and courses that might assist in providing the vocational skills that a twenty-first century workforce needs. To be truly successful in promoting both expansion of access and improvement in the quality of education, the MOOCs and their relatives will need to (1) employ excellent technology, (2) foster excellent pedagogy, (3) apply the results of learning science, (4) deploy new techniques of big data analysis to provide rapid feedback to teachers and learners, and (5) cultivate an online social ecosystem to enhance peer-to-peer learning and teaching. Although the jury is out, and there are legitimate reasons to be skeptical, PCAST believes that all of these conditions for success can potentially be met.

The recommendations that follow reflect PCAST's thinking about how the Federal Government might most effectively contribute to achieving the potential of MOOCs to help address the Nation's challenges in higher education. Going forward, we intend to explore the potential of information technology to improve K-12 education, technical training, and adult education as well as higher education, and we will report on our findings in the future.

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[18] "Our Proven Results: Evidence Based Design." *Open Learning Initiative.* Carnegie Mellon University. Web. 6 Dec. 2013. < http://oli.cmu.edu/get-to-know-oli/see-our-proven-results/>.

Recommendations:

PCAST considered what steps the Federal Government could take to encourage the development of MOOCs, to help the Nation derive the fullest benefit from new educational technologies. We have three specific recommendations.

1. *Let market forces decide which innovations in online teaching and learning are best.* The new, scalable, interactive platforms that allow real-time feedback, adjustment, and assessment are still in their infancy. Many vendors and providers are likely to emerge, introducing further technological innovations and highly differentiated educational materials. Some will use existing platforms; others will develop new ones. Some will partner with existing universities; others will engage their own faculties and compete with existing universities. As in any infant industry, the trajectory of innovation is almost impossible to predict. For this reason, it would be premature to bias the competitive process by subsidizing any one particular approach to the exclusion of others. It would also be premature to impose standards and regulations that might impair the power of competitive market forces to motivate innovation. The Federal Government can best encourage innovation in this critical sector by letting the market work.

2. *Encourage accrediting bodies to be flexible in response to educational innovation.* College degrees in the United States are accredited primarily by regional nonprofit organizations whose members collaborate in accrediting one another.[19] These organizations, on the whole, do a reasonably good job of quality assurance, but they have many standards (concerning the adequacy of physical facilities, library collections, etc.) that are irrelevant to providers of online courses and degrees. The Federal Government (and in particular, the U.S. Department of Education) should continue to encourage the regional accrediting bodies to be flexible in recognizing that many standards normally required for an accredited degree should be modified in the online arena; it should also encourage such flexibility in state oversight of education.[20] If the bar for accreditation is set too high, the infant industry developing MOOC and related technology platforms may struggle to realize its full potential.

3. *Support research and the sharing of results on effective teaching and learning.* One of the foremost advantages of MOOCs and related technologies is their capacity to capture massive amounts of real-time data on the effectiveness of different curricular materials and different approaches to teaching – thereby stimulating rich and rapid experimentation and analysis. The data might also permit advances in our understanding of learning differences, including those associated with gender, ethnicity, and economic status,

[19] For an overview of U.S. accreditation processes – which are not widely understood – see "Accreditation in the United States." *ED.gov*. U.S. Department of Education. 2 Dec 2013 Web. 6 Dec 2013. <http://www2.ed.gov/admins/finaid/accred/index.html>. Also see Eaton, Judith S. "An Overview of U.S. Accreditation." *Council for Higher Education Accreditation (CHEA).* Aug 2012. Web. 6 Dec 2013. <http://www.chea.org/pdf/Overview%20of%20US%20Accreditation%202012.pdf>.

[20] The Department of Education has urged accrediting agencies to focus more on educational outcomes, as opposed to inputs such as facilities. See Martha, Kanter. "National Advisory Committee on Institutional Quality and Integrity (NACIQI) S2013 Meeting." 6 June 2013. Web. 6 Dec. 2013. <http://www2.ed.gov/about/bdscomm/list/naciqi-dir/2013-spring/naciqi-remarks-dr-kanter-060613.pdf>.

among many other subjects. Improved knowledge and rapid feedback may accelerate the improvement of educational materials and approaches in general and the development of customized materials for different types of students.

MOOC providers will surely have the incentive to analyze such data in order to improve their educational offerings. But there would be huge societal advantages to the widespread sharing of such data, and the colleges and universities offering the courses will appreciate this benefit more readily than for-profit platform vendors.[21]

To realize these advantages, and in keeping with your plan to make the Federal Government a "catalyst for innovation,"[22] PCAST recommends the continued development and support of competitive extramural grant programs for independent research on the effectiveness of online teaching and learning. Such research would facilitate understanding of what works and what does not, and it would bring results into the public domain that might otherwise remain proprietary.[23] It would also create incentives for university faculties to study the subject, engage with the new technologies, and create incentives for university administrations to persuade MOOC platform vendors to allow researchers access to the data generated by their courses. In addition to funding independent research, the funding agencies might also organize regular conferences to help build a community among those studying the effectiveness of online education and those providing it.

The Federal Government might also consider sponsoring the development of a national exchange mechanism for the data produced by the various experiments and a national center for high-scale machine learning on these data. Making such a center widely available to researchers could further accelerate the evolution of pedagogy.[24]

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[21] Carnegie Mellon University has recently announced its intention to create a center for sharing data on teaching and learning, see Walters, Ken. "Carnegie Mellon Creates Simon Initiative To Drive Better Understanding of Student Learning Using Emerging Educational Technology Platforms." *Carnegie Mellon University.* 11 Nov. 2013. Web. 6 Dec 2013. <http://www.cmu.edu/news/stories/archives/2013/november/nov11_simoninitiative.html>.

[22] Office of the Press Secretary. "FACT SHEET on the President's Plan to Make College More Affordable: A better Bargain for the Middle Class." *The White House.* 22 Aug. 2013. Web. 6 Dec. 2013. <http://www.whitehouse.gov/the-press-office/2013/08/22/fact-sheet-president-s-plan-make-college-more-affordable-better-bargain-/>.

[23] The National Science Foundation supports some relevant research, especially where it can be related to teaching and learning in science, technology, engineering, and mathematics (STEM); see "Improving Undergraduate STEM Education." *Directorate for Education and Human Resources (EHR). National Science Foundation*. Web. 6 Dec. 2013. <http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=504976&org=EHR&sel_org=EHR&from=fund>.
and the Cross-Directorate Initiative, "Cyberlearning: Transforming Education." *Crosscutting*. *National Science Foundation*. Web. 6 Dec. 2013. <http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=503581>. Under Cyberlearning, a spring 2013 award created a "Center for Innovative Research on Cyberlearning (CIRCL)" as a clearinghouse and resource for collaboration among initiative grantees. Broad, sustained support of such sharing of lessons learned and new ideas is needed. Although private philanthropy (such as the MOOC Research Initiative launched by the Bill & Melinda Gates Foundation < http://www.moocresearch.com/>) can also be helpful, Federal funding is key to a comprehensive effort.

[24] Participants in PCAST's August 29, 2013 workshop were enthusiastic about the potential for research and new research infrastructure to (a) advance the technology, (b) connect cognitive/learning science with computer science in the design and implementation of educational technology, (c) facilitate customization, (d) foster open technology and content portability, (e) develop demonstrations of what is possible, and (f) share insights—dissemination of educational research is key to benefiting from it.

We hope that we have provided you with some useful insights and constructive recommendations that might hasten the time when open and equal access to higher education becomes a powerful reality.

Respectfully submitted,

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