Changing the Production Function in Higher Education

by Candace Thille
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Preface

Improving productivity in higher education is essential to strengthening the nation and positioning it to remain competitive in a global marketplace. Without sufficiently increasing student access, enrollment, and attainment in our higher education institutions, the United States risks being surpassed by other nations, becoming less competitive, and failing to tap the full potential of its citizenry. According to the American Council on Education’s (ACE) Minorities in Higher Education 2010 Status Report, the tradition of young adults in the United States attaining higher levels of education relative to prior generations has stalled, and for some racial and ethnic groups, the percentage of young adults with some type of postsecondary degree has actually fallen.

ACE believes that postsecondary education institutions and systems must be open to cutting-edge strategies that enhance productivity, with the end goals of expanding capacity, improving teaching and learning, and better serving an increasingly diverse, 21st-century student population. At the core of significant and sustained progress in advancing productivity in U.S. colleges and universities are leaders who understand the challenges and have the right tools to effect and lead a new era of progress and innovation on their campuses.

To this end, ACE and the Forum for the Future of Higher Education, with the support of Lumina Foundation, have launched Making Productivity Real, an initiative designed to foster a national conversation around the topic of academic productivity. This paper, Changing the Production Function in Higher Education, is the second in a series that seeks to provide campus leaders with the latest scholarship and perspectives in this critical area. Authored by scholar Candace Thille, this essay is based on a concurrent session delivered at ACE’s 94th Annual Meeting held in Los Angeles in March 2012.

For additional information on the Making Productivity Real series, please contact me at dcordova@acenet.edu or (202) 939-9481.

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The Organization for Economic Cooperation and Development’s 2009 *Education at a Glance* report, which noted that the U.S. had fallen to position number 10 in higher education completion rates when compared with other advanced post-industrial democracies, was a clarion call nearly as dramatic as Sputnik’s signal that reached Earth on Oct. 4, 1957. Both engendered deep and immediate anxiety over threats to the nation’s preeminence. In 1957, the concern sparked the creation of the Defense Department’s Advanced Projects Research Agency, and a much-needed revolution in scientific education in the U.S., which ultimately resulted in the National Defense Education Act (NDEA). The NDEA was designed to increase the scientific competence of America’s workforce. It enabled many more young people to afford a college education. It also positioned traditional higher education as a public good in service of the national interest.

President Obama is again leveraging the concern over American preeminence, and putting higher education back on the national agenda. The president’s goal: by 2020, America will be able to lay claim once again to the highest proportion of college graduates in the world. To achieve this goal, higher education in America faces the seemingly impossible challenge of serving more students, serving a greater variety of students, and reducing the cost of instruction—while simultaneously improving quality.

Merely tweaking longstanding strategies to achieve incremental improvement is no longer enough. Not only is there a need to seek entirely new approaches, insights and models, but that need is urgent. New approaches offer scalable processes that help colleges lower cost-per-degree and make significant improvements to student learning outcomes and retention rates. Insights from the science of learning combined with advances in information technology and alternative models of course design, implementation, and evaluation show promise in supporting traditional higher education to change the production function and meet the seemingly impossible challenge.

In the first paper in the *Making Productivity Real* series: *The Innovative University: Changing the DNA of Higher Education*, Henry Eyring and Clayton Christensen make a compelling case for change beyond the moral imperative to serve the national interest and meet the president’s challenge. Using Christensen’s model of disruptive innovation, Eyring and Christensen warn that, with accrediting bodies and state and federal governments more focused on learning outcomes, and with the steady improvement of low-cost online learning technology, the prospect of competitive disruption of traditional universities is real.

“It’s not teaching that causes learning. Attempts by the learner to perform cause learning, dependent upon the quality of feedback and opportunities to use it.”

—Grant Wiggins, President, Center of Learning Assessment
In addition to increasing graduation rates, much of the public and policy attention has focused on the cost of higher education. According to the National Center for Education Statistics (NCES), between the 1999/2000 and 2009/10 academic years, prices for undergraduate tuition, room, and board at public institutions rose 37 percent, and prices at private institutions rose 25 percent, after adjustment for inflation. From 1982 to 2006, the cost of higher education in the United States increased 439 percent, far outstripping the consumer price index, which increased 106 percent over the same period. Reducing cost and increasing productivity has become part of the national goal.

In 1957, the national strategy was to provide sufficient funding so that many more students could afford a college education. In the face of reduced state budgets and escalating costs, in 2011 the focus shifted to reducing the cost of higher education. As Clay Christensen points out, “Changing circumstances mandate that we shift the focus of higher education policy away from how to enable more students to afford higher education to how we can make a quality postsecondary education affordable.”

Part of the explanation for the increasing cost in higher education is that the service that higher education provides has become increasingly complex and expensive. As knowledge expands, the breadth and scope of what students are expected to learn in undergraduate courses expands. For example, breakthroughs in genetic research and in understanding cellular organization has reshaped our sense of how life evolves, and has dramatically increased the topics to be covered in an introductory biology curriculum. Likewise in engineering, the physical and social sciences, and the humanities, the flood of new material has been staggering. In addition to mastering the ever-increasing amount of basic domain knowledge, students are expected to be able to synthesize and apply that knowledge in new contexts; to develop more complex reasoning, critical-thinking and problem-solving skills; and to demonstrate expertise in communication, collaboration, and global competencies. Higher education is being asked not only to teach more complex concepts and skills to more students but also to teach a student population that enters college with much greater variability in background knowledge, relevant skills, and future goals.

Additional explanations of the high cost of higher education abound, and include: efforts to improve services to students and the professional lives of faculty; inefficient management practices; new requirements for complying with government regulations; increased capital equipment costs associated with teaching increasingly complex topics requiring more expensive technology; and two, often competing economic theories—Howard Bowen’s “revenue theory of costs,” and William Baumol and William Bowen’s “cost disease” theory. The basic idea of Howard Bowen’s revenue theory of cost is that colleges and universities will spend everything they have, so if their revenue is increased, their costs will increase too, creating a spiral. This view seems to dominate the views of many public policy leaders.

The economic theory that is the alternative explanation to Howard Bowen’s is the analysis of price pressures in all service industries first described by William Baumol and William Bowen in 1965 and again by Baumol in 1967, when he explicitly identified instruction as one service subject to seemingly uncontrollable upward price pressures. Their explanation of these rising costs has come to be known as Baumol and Bowen’s “cost disease.”

Baumol and Bowen described how labor-saving productivity growth occurs rapidly in sectors that can use productivity-enhancing automation. By comparison, the costs in sectors in which human attention is indispensable and cannot be replaced or extended by productivity-enhancing automation, such as education and live artistic performance, must persistently follow a trajectory
that exceeds the rate of inflation. As Baumol and Bowen illustrated, “A half-hour horn quintet calls for the expenditure of 2.5 man hours in its performance, and any attempt to increase productivity here is likely to be viewed with concern by critics and audience alike.” It is not that the musicians are unproductive, it is just the nature of the work musicians do. So, too, with college professors: it still takes the same number of faculty hours to teach introductory chemical engineering as it did in 1950, yet faculty salaries have risen to keep pace with rising wages in the broader economy, and so costs continues to rise.

As Baumol and Bowen projected in 1967, “Without a complete revolution in our approach to teaching there is no prospect that we can ever go beyond these levels (or even up to them) with any degree of equanimity.” All explanations of the productivity problem in higher education drive us to one conclusion: in the current context, the traditional process for developing, delivering, evaluating, and sharing learning environments is too costly, is ineffective, does not scale, and cannot support the volume and diversity of students that need to attain a postsecondary education.

In an effort to increase productivity, institutions and systems have made moves to reduce duplication and waste in administration and consolidated departments and, in some cases, even colleges. There are examples of traditional institutions setting up completely autonomous business units to experiment with radically different models for teaching and learning. Many institutions are attempting to make productivity improvements in the core teaching function by restructuring the curriculum, engaging in course redesign, or by moving courses online.

Much has been written about the power of online technologies to improve productivity in the teaching and learning process in higher education. The most obvious benefit of online technology is that it reduces barriers to access. The new technologies for learning also allow us to provide better access to reach the full spectrum of typical learners. One of the most important principles in the universal design for learning is to provide options. While providing options is difficult in a physical environment, it is much easier within the flexible and multimodal environment of online technologies.

"Improvement in Post Secondary Education will require converting teaching from a 'solo sport' to a community based research activity.”

—Herbert Simon, Late Professor at Carnegie Mellon University; Winner, Nobel Prize in Economics, 1978

The online technologies also reduce barriers to access by making the sharing of material easy and inexpensive. Many institutions are now recording lectures and making those recordings available as an educational resource to both matriculated students and the world at large. Providing 7x24 online access to lectures is viewed as a possible path for lowering the cost per student because more students can watch a lecture at only the incremental cost of recording and webcasting the lecture. Related to this benefit of increased access is the benefit of convenience. As Christensen tells us, as the very definition of quality changes in the process of disruptive innovation and in several sectors of higher education, convenience is becoming one of the new measures of quality.

The technology, though, provides more benefits than convenience and access to materials. Computer simulations allow students to explore complex ideas and phenomena at different scales of size and time. Students can experiment with the processes of chemical reactions, experiment with equilibrium at the molecular level, rotate crystalline structures, build and test the strength of bridges, or intervene in complex ecosystems or population dynamics. In the past few years, the networking power of technology has also been leveraged to provide learners with access to a much wider pool of
expertise, guidance and support, and to foster participation in social learning communities—beyond the walls of a school or home.

As the rush to go online continues, many discussions of educational technology grow into debates about the value of online learning compared to traditional face-to-face instruction. Not surprisingly, the literature supporting that debate reports conflicting results. On the one side, the large Meta-Analysis and Review of Online Learning Studies, conducted by SRI and produced by the U.S. Department of Education in 2009, reported that students who took all or part of a course online performed better, on average, than those who took the same course through traditional face-to-face instruction. The report further stated that learning outcomes for students who engaged in online learning exceeded those of students who received face-to-face instruction. Other studies conducted with community college students have found that students were more likely to fail or withdraw from online courses than from face-to-face courses, and that students who took online coursework in early terms were slightly but significantly less likely to return to school in subsequent terms. At the same time, students who took a higher proportion of credits online were slightly but significantly less likely to attain an educational award or transfer to a four-year institution. While continuing to study the impact of online learning on completion is important, the question to be answered is not “is online education as good as (or better than) traditional education?” but rather, “how can the technology be used most effectively to support and accelerate colleges’ efforts to dramatically increase student progress and completion?”

Traditional colleges and universities are using technology in a variety of ways with the goal of reducing cost and improving student success. There is a growing body of literature on the specific advantages of each technology for its learning function, and the list grows with each new invention. New technologies are steadily emerging, often more quickly than empirical validation of relative effectiveness can document. For new and emerging learning technologies, it is important to develop new methods for empirically evaluating and improving the technologies and the teaching and learning processes they support on a much faster schedule.

Our institutions of higher education spend few resources on providing students and faculty data that would tell them whether the new technologies or the traditional individual and collective processes for learning and teaching are effective. Without evidence that distinguishes technologies and instructional strategies that are effective in changing the knowledge state of students from instructional strategies that are ineffective in producing those results, it is difficult to improve the current state. In lieu of data, we depend on faculty intuitions about what works and what doesn’t. While those intuitions are certainly sometimes right, it is unlikely that intuition alone is sufficient as a means to improve instruction. This approach is thoroughly unscientific and incapable of producing the persistence, spread of adoption, and iterative improvement that is required to bring about transformative change.

Fortunately, an emerging marriage of the science of learning and technology challenges the belief, grounded in the Baumol/Bowen analysis of productivity in the services sector, that improving productivity in education necessitates a reduction in quality. While such a negative correlation between quality and productivity has in fact often held when class sizes were increased in attempts to increase productivity, when television was used to broadcast lectures, or when traditional teaching methods were directly transferred to the web, that correlation is not inevitable. Learning and brain scientists are making extraordinary advances in our understanding of human learning. The results of that research can be used to inform the design of learning environments that can be developed and
shared through the use of technology. One example of combining the results of learning research with the affordances of the technology to improve learning is the Open Learning Initiative at Carnegie Mellon University (OLI).²⁰

“OLI is an amazing and critical piece of work.... The idea of these virtual labs and intelligent tutoring systems, I think, can really revolutionize education. And we need to revolutionize education.”

—Bill Gates, Co-chair and Trustee of the Bill & Melinda Gates Foundation

OLI is an open educational resources project that began in 2002 with a grant from The William and Flora Hewlett Foundation. Unlike many other open educational resources projects, OLI courses are not mere collections of material created by individual faculty to support traditional instruction. The original and most challenging goal of the project was to develop web-based learning environments that could support an individual learner who does not have the benefit of an instructor or class, to achieve the same learning outcomes as would be expected of a student completing the traditional course at Carnegie Mellon. This challenging goal led Carnegie Mellon to build on its institutional strengths in cognitive science, software engineering, and human-computer interaction to develop an interdisciplinary methodology for creating new forms of online instruction.

Teams of faculty content experts, learning scientists, human-computer interaction experts, and software engineers work collaboratively to develop the OLI courses. The OLI design team articulates an initial set of student-centered observable learning objectives and designs the instructional environment to support students to achieve the articulated objectives. The instructional activities in OLI courses include small amounts of expository material and many activities that capitalize on the computer’s capability to display digital images and simulations and promote interaction. Many of the courses include virtual lab environments that encourage flexible and authentic exploration. Perhaps the most salient feature of OLI course design is found in the quasi-intelligent tutors—or “mini-tutors”—embedded within the learning activities throughout the course.

OLI benefits from inheriting some of the best work done in the area of computer-based tutoring by Carnegie Mellon and University of Pittsburgh faculty. An intelligent tutor is a computerized learning environment whose design is based on cognitive principles and whose interaction with students is based on that of a human tutor, that is, making comments when the student errs, answering questions about what to do next, and maintaining a low profile when the student is performing well. This approach differs from traditional computer-aided instruction in that traditional instruction gives didactic feedback to students on their final answers, whereas the OLI tutors provide context-specific assistance during the problem-solving process.

Embedded assessments, interactive activities, and tutors in OLI courses are designed to provide support to students, but they have an additional purpose: they collect data. One unique power of contemporary educational technology is its ability to embed rich forms of assessment into virtually every instructional activity and use those activities to collect fine-grained student learning data. With the students’ permission, the OLI system digitally records interaction-level detail of student learning actions in all OLI courses and labs. These data were originally collected by OLI because the design teams could not directly observe the learners using the environment. Rather, the team depended on analyzing the data stream to see what was working and not working to produce improvements in the next iteration of the course. A year into the project, the data were put to another use—to support research about how people learn.
In 2004, the National Science Foundation funded the Pittsburgh Science of Learning Center (PSLC), co-managed by Carnegie Mellon University and the University of Pittsburgh, to study the nature of human learning. The PSLC has two main goals: to enhance scientific understanding of robust learning in educational settings and to create a research facility to support field-based experimentation, data collection, and data mining. PSLC is advancing both basic research on learning in knowledge-rich settings and applied research by contributing to a scientific basis for the design and engineering of educational approaches that should have a broad and lasting effect on student achievement. The PSLC uses the OLI development, delivery, and data collection environment as well as some of the OLI courses as a core research platform. Using the OLI courses, PSLC researchers design experiments that combine the realism of classroom field studies and the rigor of controlled theory-based laboratory studies. The old view that the processes of learning are too complex to yield to scientific understanding is no longer tenable.

The premise of the science of learning, still a young field, is that much of student learning is driven by a set of learning mechanisms. The goal of the science of learning is to articulate these mechanisms and thereby describe, explain, and predict human learning. While many in the education system say they “know what works,” based on apparently successful efforts in particular classes or at particular institutions, the descriptions of “what works” are often complex exemplars that are challenging to replicate and scale. Often, when particular instructional interventions are identified as being effective, they seldom persist beyond the practice of an individual faculty member and, even when replicated, often do not “work” in the new context or for the new population.

When the precise underlying mechanisms of learning are not known, instruction must be provided through “intuitive instruction,” in which quality instruction is provided only by talented professionals or those with a long history in teaching. However, as patterns in student learning are studied by scientists and the underlying mechanisms of learning are articulated and tested,
instruction can evolve into the realm of “evidence-based instruction,” where data are gathered to show that certain approaches are better than others and to stipulate the contexts in which they are likely to work.

“I have been on record for some time as being skeptical about the likely effects on productivity in higher education of various new technologies.... But the evidence...about the work at Carnegie Mellon has caused me to re-think my positions...”
—William G. Bowen, President Emeritus, Andrew W. Mellon Foundation and Princeton University

Learning is complex and to adapt, replicate, and scale effective instructional practice, higher education needs to be able to describe what works as a set of underlying mechanisms that are influenced by a set of student and contextual variables. In other words, higher education needs better theories of learning that inform both teaching practice and the design of educational technology. To develop better theories, learning researchers need more data from more students in more contexts. The synergistic relationship between OLI and the PSLC is an example of how traditional institutions of higher education can leverage the dual mission of research and teaching to create a virtuous cycle for continuous improvement in higher education's production function. OLI uses results of the science of learning to drive the design of the educational technology, and the OLI technology collects the data that PSLC learning researchers need in order to better understand and articulate the underlying mechanisms of human learning.

OLI courses were originally designed to serve independent learners, but over time, faculty adopted the courses to support traditional instruction. In this new use, OLI found that the richness of the data the system collects about student use and learning provides an unprecedented opportunity for keeping instructors in tune with the many aspects of their students’ learning. Dr. Marsha Lovett, a cognitive scientist at the Eberly Center for Teaching Excellence at Carnegie Mellon, has been leading the team that is designing the OLI Instructor Learning Dashboard. The dashboard analyzes and distills the click-stream data that are automatically collected from the student's interactions with the system. Based on an underlying knowledge model, the Learning Dashboard communicates key information on the students’ learning and progress that will help guide instruction in real time. Unlike reports from traditional course management systems, the Learning Dashboard presents instructors with a measure of student learning for each learning objective. The dashboard also provides more detailed information, such as the class’s learning of sub-objectives, learning predictions for individual students, and the types of tasks with which the students are struggling the most.
OLI represents one example of the “killer application” of web-based learning environments on networked devices—the ability to continuously gather data about student learning and use those data to fuel research in how people learn, direct the improvement of the learning environment, and support faculty and students in the learning process. In some ways, it is what Google, Netflix, and Amazon have figured out using their collaborative filtering techniques. The power of the web-based
environments is not just to push out information and services, but also to use the data from the use of the service to build a model of the user to better target the service offered. Rather than building models of an individual as consumers based on their movie preferences or buying patterns, OLI builds models of individuals as learners based on their interactions with the learning environment.

The OLI is based on a constant research cycle: research informs the design of the course, and the data collected through student use of the course fuels not only feedback to students, instructors, and course design teams but also fuels research studies.

Evaluation studies have been conducted at institutions spanning a range of Carnegie classifications and have shown accelerated learning\textsuperscript{22}, reduced attrition\textsuperscript{23}, and significant correlations between OLI learning activities and learning gain\textsuperscript{24}.

\textbf{DATA COLLECTION AND ANALYTICS}

President Obama has reminded the country that higher education is a public good; he has set aggressive national goals and challenged higher education leaders to find ways to make colleges more affordable while producing more graduates. Actors in all segments of the education system are becoming acutely aware of the need to make data-driven decisions at every level on the basis of what is best for each and every student; decisions that, in aggregate, will lead to better performance across the entire system. The data that are needed to support such decision-making are collected, stored, and analyzed in multiple repositories and at multiple levels of granularity.

States fund the institutions that enroll about three-quarters of the nation’s college students and have historically held the primary responsibility for shaping higher education policy and for setting the public agenda for higher education. To meet the national goal, many states have set goals for increases in bachelor’s degrees, associate degrees, and postsecondary certificates, including for low-income populations. Information on the progress toward, and degree completion of, all students in higher education is critical for state leaders to gauge whether their policies are successful and to take informed action.

The working group on common college completion metrics convened by the National Governors Association (NGA) has made a good start at defining common higher education measures that states collect and report publicly. As the NGA has recognized, a key part in addressing the challenge of increasing attainment and academic productivity is collecting and analyzing data that can be used to support students, institutions, and state and federal policymakers in developing an appropriate path forward\textsuperscript{25}. Cross-institutional, system-wide, or state data systems generally collect and provide what we can think of as macro-level data.
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Individual institutions and departments are beginning to use the data collected in the student information systems and traditional learning management systems to support decision-making. Using information about student behavior collected by the learning management system, such as log-ins, site engagement, and pace, some colleges compare a student’s behaviors against historical data collected from other students. By using this system to analyze the timing and frequency of student log-ins, these colleges have been able to predict with 70 percent accuracy those students who are at high risk to not be successful in a course. Institutional student information systems and traditional learning management systems collect and provide what we can think of as micro-level data. Such systems can supplement a college’s ability to recognize an at-risk student, but the data collected in these systems does not provide detailed enough information to give evidence-based guidance in how to intervene effectively.

New learning platforms, such as OLI, which monitor student interactions with learning activities, collect and provide what we can think of as nano-level data. Forming data-based recommendations on program design, course design, or a specific learning intervention given an individual’s context, demographics, behavior patterns, and knowledge states will require discovering and analyzing patterns across all levels of data.

The challenges to realizing the vision of collecting and using data across classrooms and across systems are both technical and regulatory. On the technical front, multiple student data systems and the lack of common standards for data formats pose formidable barriers to the development of multilevel data collection and analysis systems. Providing meaningful, actionable information to all stakeholders in the education system will require building agreement on the technical processes for sharing data that are collected across multiple levels and multiple systems.

Legislation such as the Family Educational Rights and Privacy Act (FERPA) serve the very important purpose of protecting the rights of individuals, but can present some barriers to data sharing. According to FERPA, institutions can share certain pieces of public information such as a student’s name and date of birth. Institutions can match their student information with National Student Clearinghouse (NSC) records without further consent. However sharing more detailed information about students with other organizations may require additional consent. Before sharing student data, organizations often need to have legal counsel review the privacy protection and consent forms of each organization to draft a data-sharing agreement that meets the privacy protection requirements of all organizations participating in the data sharing.

Higher education needs ongoing integrated research that supports innovation and the evaluation of interactive teaching strategies and technologies in various contexts. Ongoing research and adaptive management is critical because the context is in flux. The domain knowledge that students are expected to learn is growing, the number and complexity of skills that students are expected to develop is growing, the number of students who are expected to achieve a college degree is growing, the variability in the student population is growing, our understanding of how people learn is growing, and the technology and the way people are using technology is changing rapidly.

Information technology can offer ways of creating, over time, a complex stream of data about how students think and reason while engaged in important learning activities that can support adaptive decision-making. Additional research is also needed on the data representations and analysis methods best suited for different audiences and objectives.
Such an undertaking to design the learning environments and data systems is not small or inexpensive and will require the cooperation of many institutions. The role of traditional colleges and universities now is to lead the process of improving postsecondary education through thoughtful, sustained, iteratively improved application of the emerging knowledge from the science of learning to the design, implementation, broad use, evaluation, and ongoing improvement of web-based learning environments. In leading this effort, traditional higher education has the distinct advantage of having the faculty who possess the domain expertise, the expertise in engaging in research, and the passion not only for their own fields of study but also for their students’ learning.

The collaborative development of the learning environments is only the first step in the process. Ideally, the learning environments will include the mechanisms for assessing both student achievement and the effectiveness of the instructional intervention as part of the teaching and learning process. Without continuous, robust assessment of instructional strategies aimed at articulating the underlying mechanisms, we will continue to see “one off” successes with little understanding of what works and what doesn’t, and how to bring effective strategies to scale.

Some faculty and institutions may see these processes as undermining the role of the faculty. But these strategies can be viewed in a very different light. The team-based, scientific design of web-based learning environments combined with rich feedback about learning can make for a much better experience for students and for faculty. In the traditional classroom, faculty operate with little data about the current knowledge state of their students and the richness of the faculty expertise is often wasted. By giving students better learning support outside of class and by giving faculty highly useful information about the students’ knowledge, precious class time can be much more effectively used. The integration of research and practice that lies at the heart of these approaches depends on the participation of a diverse community of developers, researchers, faculty, and learners. By leveraging information technology for access to detailed and timely assessment, in conjunction with developing feedback loops between research science and the teaching process, both the quality and production function in higher education will be improved.
NOTES


2 DARPA History http://www.darpa.mil/About/History/History.aspx

3 U.S. Department of Education. The Federal Role in Education http://www2.ed.gov/about/overview/fed/role.html

4 In his first joint address to Congress on February 24, 2009, President Obama set a goal that the nation should once again have the highest proportion of college graduates. http://www.whitehouse.gov/sites/default/files/completion_state_by_state.pdf


6 National Center for Education Statistics (NCES) Trends in cost of a college education http://nces.ed.gov/fastfacts


9 See the discussion on the “administrative lattice” and “academic ratchet” in, Robert Zemsky, Gregory R. Wenger, and William F. Massy, Remaking the American University: Market-Smart and Mission-Centered (Rutgers University Press, 2006)


15 See for example, the new campus of University of Minnesota at Rochester, which has a new new bachelor’s program in health sciences that was designed completely from the ground up.

16 Carol A. Twigg, “Improving Quality and Reducing Costs: the Case for Redesign” (Lumina Foundation, 2005), pp. 46, 48


21 For more information about the Pittsburgh Science of Learning, visit their website at http://www.learnlab.org/


ABOUT THE AUTHOR

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Candace Thille is the director of the Open Learning Initiative (OLI) at Carnegie Mellon University, a position she has held since the program’s inception in 2002. She is also the co-director of OLnet. Jointly run by Carnegie Mellon and the Open University in the UK, OLnet is an international open educational research network. Candace’s focus of research and development is in applying results from the learning sciences to the design, implementation, and evaluation of open web-based learning environments. Candace serves as a redesign scholar for the National Center for Academic Transformation; as a Fellow of International Society for Design and Development in Education; on the technical advisory committee for the AAU STEM initiative; and on the Global Executive Advisory board for Hewlett Packard’s Catalyst Initiative. She has served on the working group at the U.S. Department of Education to co-author the National Education Technology Plan and on a working group of the President’s Council of Advisors on Science and Technology to write a report for the Obama Administration on improving STEM higher education.