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Technology: The Solution to Higher Education's Pressing Problems?

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Abstract

No book designed to inform understanding of how higher education is influenced by and responds to societal changes, demands, and progress would be complete without a chapter on technology. Defined as "the application of scientific knowledge to the practical aims of human life," technology is a fundamental element of any society.[1] Technology is more than cutting-edge, advanced, "high-tech" innovations and is not limited to "technology sectors" like aerospace, nanotechnology, and robotics. Rather, the term "technology" refers to the tools that are available in the society in which we live and work, and that may be applied and leveraged to achieve various goals and purposes.

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Chapter Fifteen

Technology

The Solution to Higher Education's Pressing Problems?

Laura W. Perna and Roman Ruiz

No book designed to inform understanding of how higher education is influenced by and responds to societal changes, demands, and progress would be complete without a chapter on technology. Defined as "the application of scientific knowledge to the practical aims of human life," technology is a fundamental element of any society.[1] Technology is more than cutting-edge, advanced, "high-tech" innovations and is not limited to "technology sectors" like aerospace, nanotechnology, and robotics. Rather, the term "technology" refers to the tools that are available in the society in which we live and work, and that may be applied and leveraged to achieve various goals and purposes.

The relationship between technology and higher education is complex and ever changing. Higher education institutions are deeply intertwined with and linked to the societies they serve. Higher education is challenged to spur societal change and progress by encouraging the development of new technologies and, at the same time, to respond to demands created by technology. This chapter begins by describing the multiple roles of technology in three core functions of higher education: producing research, enrolling and supporting students, and teaching and encouraging learning. The chapter then considers the vexing question, *can technology solve the pressing problems facing higher education?* More specifically, *can technology enable higher education to increase access and attainment while also reducing costs and maintaining quality?* The final section of the chapter considers the barriers that limit the extent to which technology can productively address these challenges and transform higher education.

Technology and Higher Education

With the ubiquity of high-speed Internet and the proliferation of mobile devices, information and communication technologies influence countless aspects of daily life and, consequently, numerous dimensions of higher education.[2] Current and prospective students, faculty, and administrators routinely use digital technologies and expect that a "modern" college or university will have state-of-the art Wi-Fi access, campus computing and technology laboratories, and web-based course management and student information systems. This section highlights the multifaceted role of technology in conducting research, enrolling and supporting students, and teaching and encouraging learning.

The Role of Technology in Research

The connection between technology and research production is multidirectional. Higher education advances the creation and application of new technologies through the production of original research. At the same time, technology also influences the ways that higher education produces research and advances knowledge across fields and disciplines.

With the goal of encouraging higher education to develop, apply, and test new technologies, federal and state governments, philanthropic organizations, businesses, and other entities annually award considerable financial resources to higher education institutions. The federal government is the largest single provider of research funding for higher education, accounting for 61 percent of the total $65.8 billion university research and development expenditures in FY2012.[3]

One recent example of the federal government's efforts to stimulate technological innovation by higher education institutions is the First in the World (FITW) Program, a competition designed to encourage the development and use of innovative technologies to improve college student outcomes and affordability. Administered by the US Department of Education's Fund for the Improvement of Postsecondary Education (FIPSE), this program awarded grants in FY2014 ranging from $1.65 million to $4 million ($75 million total) to twenty-four higher education institutions. Of the twenty-four pilot projects that received funding, six focused on using technology to improve students' educational outcomes. Examples include the Georgia Institute of Technology's Center for

Accessible Materials Innovation project, which expands access to digital instructional content for students with print-related disabilities and Northeastern University's Lowell Institution Innovation Incubator project designed to increase student engagement and motivation in online STEM courses.[4]

Research institutions can be drivers of economic and technological advancement in their regions by encouraging the creation of technology parks and technology firms (e.g., Silicon Valley in Northern California and the Research Triangle in North Carolina) and engaging in partnerships with technology firms.[5] A number of US research universities have created technology transfer offices (or similarly named units) to facilitate (and monetize) the transfer of university-generated technologies into the private sector. Technology transfer offices are typically charged with advising university researchers on how to identify, patent, and market "commercially viable technologies" to potential licensees.[6]

According to a 2013 survey of more than 200 US research institutions, technologies created by university researchers contributed to the development of 719 new commercial products by companies licensing the technologies in FY2013.[7] Association of University Technology Managers (AUTM) member institutions also self-reported that "more than 10,000 patented products currently being sold originated in academic research laboratories."[8] The engagement of higher education institutions and faculty in market activities like patenting and licensing new technologies is consistent with the theory of academic capitalism as advanced and updated by Sheila Slaughter and Gary Rhoades.[9]

In addition to contributing to the development of new technologies, higher education has also incorporated and applied new technologies to change the process of knowledge production. Higher education researchers now operate within the context of a "cyberinfrastructure"[10] that includes the "distributed computer, information, and communication technologies combined with the personnel and integrating components that provide a long-term platform to empower the modern scientific research endeavor."[11] Low-cost information and communication technologies enable teams of researchers to collaborate in all aspects of a research project, from developing research grants, collecting and analyzing data, and authoring publications and other research products, regardless of where team members are physically located. With e-mail, Skype, FaceTime, and other web-based applications, researchers across the globe are now part of an interconnected "global grid of investigation and inquiry."[12] Low-cost software and enhanced data storage capacity also enable researchers to analyze larger databases using increasingly sophisticated analytic methods.

The knowledge production process has also been changed by Internet technologies that provide easy and broad access to research products and materials. Digital libraries and repositories (e.g., JSTOR, Artstor) make scholarly publications and resources electronically accessible anytime to researchers across the globe. For instance, JSTOR, a not-for-profit organization established in 1995, provides shared digital access to current and historical issues of over 2,000 academic journals for scholars at more than 9,200 institutions in more than 170 nations.[13] Accessing these digital collections may create additional costs for higher education institutions (as JSTOR and other repositories typically charge a fee to member institutions) but may also reduce the costs associated with storing and maintaining paper copies of materials in an institution's own library.

With the availability of Internet technologies and interest in low-cost methods of distributing academic research worldwide has also come open access publishing, defined as "unrestricted online access to articles published in scholarly journals."[14] As of December 2014, the Directory of Open Access Journals (doaj .org), an online index of peer-reviewed open access (OA) journals, cataloged 1.8 million articles from 10,200 journals from 136 countries. Suggesting widespread support of OA, 89 percent of more than 38,000 researchers with peer-reviewed publications who responded to a 2010 international survey reported that OA publishing is or would be beneficial to their field.[15]

Federal agencies and nonprofit organizations in the US have encouraged the advancement of OA publishing. Since 2009 the National Institutes of Health (NIH) has required that grant recipients submit accepted publications to its own PubMed Central, a free digital archive, within twelve months of official publication.[16] In 2013 the federal Office of Science and Technology Policy directed all federal agencies with more than $100 million in research and development expenditures to adopt OA policies similar to NIH.[17] Beginning in 2015, the Bill & Melinda Gates Foundation has required that all new foundation-funded research be freely available online with immediate access and reuse rights.[18]

The Role of Technology in Enrolling and Supporting Students

The relationship between technology and students is also multifaceted. Students, parents, employers, governments, and other stakeholders expect that higher education will both produce graduates with the knowledge and skills required in a technologically driven, knowledge-based economy[19] and use current technologies to recruit and support students. Technology influences the characteristics of both the "product" that higher education is expected to produce and the expectations of individuals enrolling in higher education, a primary "input" into higher education.

Today's knowledge-based economy requires highly skilled workers who are able to use new technologies.[20] Some argue that increasing the supply of highly skilled workers is critical to not only ensuring the nation's future international competitiveness but also to reducing economic inequality.[21] In their examination of "the race between education and technology," Goldin and Katz observe that, in the first part of the twentieth century, increases in educational attainment kept pace with "skill-biased technological change."[22] Employers' demand for highly skilled workers—defined during this time period as workers with a high school diploma—was met with the available supply. During the last quarter of the twentieth century, however, growth in educational attainment slowed, and the demand for highly skilled workers—now defined as workers with a college degree—exceeded the supply.[23] Goldin and Katz conclude that the growth in economic inequality that occurred in the United States during the last quarter of the twentieth century is explained not by growing demand for the skills created by "the era of computerization," but rather by an insufficient increase in the supply of workers with the skills to use the new technologies.[24]

Increasingly the jobs that are available today—and the jobs that are projected to be available in the future—require workers to have information-processing, academic, and technical skills.[25] Suggesting the importance of technological skills, the Organisation for Economic Co-operation and Development now defines "adult basic skills" not only by measures of literacy and numeracy, but also by indicators of the ability to read digital texts and solve problems in environments that rely on information and communication technology.[26] Employers appear to reward technological expertise, as average earnings are higher for individuals who use computers than for those who do not, regardless of educational attainment level.[27]

Higher education institutions are expected to not only produce graduates with the skills required for available jobs in a technologically driven, knowledge-based economy, but also utilize practices that recognize the changing technological expectations and habits of entering students. The use of personal computers and the Internet is commonplace, especially for individuals born after 1980.[28] Today virtually all teens (ages twelve to seventeen) and young adults (ages eighteen to twenty-nine) use the Internet, and most teens own or have access to a desktop or laptop computer in their home (93%) and own a cell phone (78%).[29]

Known as "digital natives," today's traditional-age (ages eighteen to twenty-four) college students are assumed to be tech savvy and fluent with new technologies, learn in fundamentally different ways than previous generations, and be enthusiastic about gaming and virtual simulations.[30]

Virtually all (89%) eighteen- to twenty-nine-year-olds who use the Internet report using social media.[31] Among college-bound seniors in 2014, 75 percent reported using Facebook, 73 percent used YouTube, and 40 percent used Twitter.[32] Recognizing that social media usage among traditional college-aged students is now near universal,[33] the 2014 *NMC Horizon Report*—an annual publication in which an international panel of technology experts predicts key technology trends—identified the "growing ubiquity of social media" as one of the "fast trends" that is influencing higher education.[34] Although some faculty and administrators continue to worry about the privacy implications of social media, technology experts point to the potential benefits of social media in creating a venue where "anyone in the social networks can engage with content."[35] Social media is a collaborative arena that permits the transmission and consumption of user-generated content, including text, photos, audio, and video. Like other web-based technologies, social media transcends physical boundaries and connects users from around the globe.

Given these statistics, it is not surprising that prospective students (and their parents) are utilizing computers and mobile devices to obtain college-related information. In a March 2014 poll, both college-bound seniors and their parents ranked the institutional website as the most influential and reliable resource used in the college search process.[36] Nearly two-thirds (61%) of college-bound seniors and half (51%) of parents reported preferring to learn about college using web-based resources. Students are accessing college websites via both computers and mobile devices. Ninety-one percent of college-bound high school seniors reported having access to a mobile device (typically a smartphone) and 71 percent reported having looked at a college website on a mobile device.[37]

These characteristics compel higher education institutions to ensure that they are providing information and services in the form and with the functionality that students and their families need and want. Colleges and universities appear to be responding to these expectations, as more than 90 percent of the public and private two-year institutions responding to a 2006 survey reported that they were offering, or were planning to offer within two years, the following online services: course registration, financial aid and admission applications, digital course catalogs, student access to class schedules, and online courses.[38]

About 83 percent of campuses responding to a 2014 survey reported having implemented, or were planning to implement within the academic year, mobile apps, up from 78 percent of campuses in 2013 and just 60 percent in 2012.[39]

Digital technologies are also being developed to help students, especially students who are the first in their families to attend college and those enrolled at under-resourced high schools, to navigate the college enrollment process. For example, in partnership with Rossier School of Education researchers, USC's Game Innovation Lab has developed *Mission: Admission*, a free-to-play game available through Facebook.[40] In the game, students assume the avatar of a high school senior and spend their finite energy supply completing activities that make them eligible for college admission such as studying in the library, completing the FAFSA on time, and requesting letters of recommendation from teachers. Researchers designed the game to develop students' resilience and grit by confronting them with real-world obstacles that demand strategy and perseverance to accomplish challenges analogous to those they will encounter in the college application process. Another computer game developed by the lab, *Graduation Strike Force*, is modeled after a traditional action game and requires students to battle mutants and monsters as they learn how to overcome the seemingly insurmountable college affordability problem.[41]

Mobile phone apps are also being created with the goal of providing high school students with better college-related information in the context of the high student-to-counselor ratios in most high schools. College Summit, a nonprofit organization with the mission of increasing college enrollment among low-income students, created the virtual *College App Map* to organize apps by high school grade level and intended purpose (e.g., college selection, career exploration).[42]

Colleges and universities may be able to capitalize on emerging technologies to create low-cost mechanisms for promoting college enrollment and persistence.[43] For instance, using a multisite experimental design, Castleman and Page found that students who received a set of automated and personalized text messages had lower likelihood of "summer melt," defined as the failure of high school graduates who intend to enroll in college to actually matriculate in the fall semester.[44] The text messages provided reminders to students and their parents about such key tasks as "register for orientation and placements tests" and "complete housing forms" and links to information and resources (e.g., FAFSA completion, advising). The text messages were particularly effective for promoting enrollment at two-year colleges and for students from low-income families, those who had less access to college planning supports, and those who had not completed the FAFSA at the time of intervention.

Some colleges and universities are using technology with the goal of delivering more effective and efficient academic advising.[45] One example is Arizona State University's eAdvisor system. With more than 73,000 students in the fall of 2012,[46] Arizona State University and other large universities may be especially motivated to identify effective, technology-driven, low-cost innovations. The electronic advising system is expected to increase the time advisors have available to provide face-to-face counseling and mentoring for students most at-risk for academic failure. Implemented in 2007, the web-accessible, automated eAdvisor system enables undergraduates, at any time or place, to explore potential majors, identify optimal course sequences, and map out curricular scenarios associated with particular major field choices. By integrating information across several institutional databases, the online system may also enable advisors to better track students' progress toward an intended degree and identify early students who are not making adequate academic progress.[47]

Some institutions are using asynchronous technology (e.g., e-mail, web portals) and synchronous technology (e.g., instant messaging) to deliver career services. Examples include Old Dominion University's online career workshops and seminars and Emerson College's podcasts featuring alumni and other professionals working in career fields of interest.[48]

Student demand for tools that better meet their information needs is further signaled by the initiative some students have taken to develop their own mechanisms for leveraging available technologies.[49] For example, a Rutgers University student built an app that monitors enrollment of the university's most in-demand courses and notifies users when an opening becomes available. Two students at the University of California at Berkeley created a website that integrates course scheduling information, professor ratings, and required textbook listings in one location. Berkeley brokered a financial deal with the students to use the website; the site now serves students at four universities within the University of California system.[50]

These last examples are consistent with another trend identified in the 2014 *NMC Horizon Report*: the shifting role of students from consumers to creators.[51] Understanding the tech-savvy nature of traditional college-aged students, some universities provide technology laboratories for students and sponsor campus-wide initiatives designed to encourage student entrepreneurship. Examples of university-sponsored innovation initiatives include the University of Pennsylvania's

AppItUP challenge, in which UPenn students compete to win investor funding to develop a mobile application, and the Harvard College Innovation Challenge (also called "i3"), in which students compete for grant funding, consulting services, and workspace in order to develop their own startup company.[52]

The Role of Technology in Teaching and Learning

The relationship between technology and teaching and learning is also complex. Higher education has both incorporated new technologies into pedagogical practices and contributed to the development of new technologies for teaching and learning. That being said, however, technology has had relatively little impact on instructional approaches at most colleges and universities. Technology hypothetically allows for the reconfiguration of the traditional face-to-face, lecture-based instructional model that has historically been the norm in higher education. Yet most observers concur that, although technology has created many changes for higher education research, technology has largely been used to enhance traditional approaches to delivering higher education without fundamentally changing the nature of teaching and learning.[53]

Since the creation of early online course delivery systems in the late 1990s, the availability of higher education over the Internet has increased considerably.[54] The 2014 *NMC Horizon Report* identifies the incorporation of online, hybrid, and collaborative learning into face-to-face classroom instruction as one of the "fast trends" in higher education technology.[55] Using data from the Integrated Postsecondary Education Data System (IPEDS), the Babson Survey Research Group reports that the majority (71%) of degree-granting higher education institutions offered at least one online course in 2013.[56] More than 90 percent of public two-year and public four-year institutions reported offering online courses, compared with about two-thirds of private not-for-profit four-year and private for-profit four-year institutions. The availability of online courses generally increases with institutional size, as only 48 percent of institutions with fewer than 1,000 students had distance course offerings in the fall of 2013, compared with more than 95 percent of institutions with at least 5,000 students.[57] Online courses may also be more common "in subjects where mastery can be evaluated in response to questions with demonstrably right or wrong answers" (e.g., math and business rather than social science), as well as in professional rather than undergraduate education programs.[58]

Student participation in online courses has increased in recent years.[59] According to IPEDS, in the fall of 2012, 11 percent of undergraduate degree-seeking students enrolled exclusively in distance education courses, while another 15 percent enrolled in some but not all distance education courses. About 26 percent of all students (including undergraduate, graduate, and nondegree-seeking undergraduate students) were enrolled in at least one distance education course in the fall of 2012.[60]

One challenge for understanding the role of "online learning" is continued inconsistency in the definition and use of the term.[61] The range of approaches to online learning limits identification of "a set of mutually exclusive 'boxes' into which various approaches to online learning can be put."[62] Despite this caveat, one category involves using technology to "replicate traditional models of instruction" by offering course content "purely online" or with a "hybrid" approach. A "rare" but different approach, what Bacow and colleagues label "interactive learning online," utilizes "increasingly sophisticated forms of artificial intelligence, drawing on usage data collected from hundreds of thousands of students, to deliver customized instruction tailored to an individual student's specific needs."[63] Whereas purely online and blended/hybrid learning approaches are instructor-guided, interactive learning online is "machine-guided."[64]

Although not transforming the underlying teaching paradigm,[65] technology has been incorporated into various instructional practices. Course management systems (CMS), like Blackboard, are now commonly used by higher education faculty to share course information, document student grades, and converse with students.[66] Used by colleges and universities as well as other organizations providing education and training, a learning management system "is a software application that automates the administration, tracking, and reporting" of courses, and collects and provides access to content and learning materials for individual users.[67]

Reflecting the increasing use of social media among college-age students, a growing share of faculty is incorporating social media into the courses that they teach.[68] The most common social media platforms that faculty report using in course assignments are blogs and wikis, followed by podcasts. Some social media platforms require greater student engagement than others. For instance, blogs and wikis require students to create content or add original comments, whereas podcasts merely require students to listen.

Some educators and researchers have identified the potential benefits of incorporating the positive elements of games and gaming into the higher education learning context.[69] Observing the many hours that individuals of all ages across the globe devote to computers, mobile phones, and video games, Jane

McGonigal, the director of game research and development at the Institute for the Future, argues that games can be a powerful mechanism for encouraging "extreme effort," "reward[ing] hard work," and promoting "cooperation and collaboration."[70] Among other attributes, games focus on accomplishing a particular goal, have rules for achieving the goal, provide feedback on progress toward goal attainment, and assure "that intentionally stressful and challenging work is experienced as safe and pleasurable activity."[71] Identified as an emerging education technology development in the 2014 *NMC Horizon Report*, gamification is "the notion that gaming mechanics can be applied to routine activities," including learning.[72] By creating "positive emotions, positive activity, positive experiences, and positive strengths,"[73] games may promote engagement in course content, especially for digital natives. Gameful learning is not a prescribed, didactic experience. Instead, gameful learning is assumed to engender voluntary acquisition of knowledge and encourage a self-initiated process of discovery.[74] Adapting the hallmarks of games into the higher education teaching-learning process has the potential to enhance educational outcomes such as critical thinking, problem solving, and teamwork.[75] Nonetheless, although gaming practices may be more scalable than traditional pedagogical practices,[76] relatively few faculty have taken the steps required to "gamify" their courses.[77]

Another emerging innovation is the application of technology to competency-based education. With attention to measuring learning rather than seat-time,[78] competency-based education promises "a flexible way for students to get credit for what they know, build on their knowledge and skills by learning more at their own pace, and earn high quality degrees, certificates, and other credentials."[79] Competency-based educational practices do not necessarily incorporate technology, but technology is integral to some competency-based education reforms, such as interactive self-paced courses that are delivered online. In January 2015 the US Department of Education signaled its interest in competency-based education and prior learning assessment by granting at least forty higher education institutions waivers from some of the federal financial aid regulations that have limited related experimentation.[80] With a grant from Lumina Foundation, in March 2014 Public Agenda launched the Competency-Based Education Network (C-BEN), an entity intended to improve understanding of effective models for and approaches to competency-based education. As of January 2015, C-BEN counted eighteen higher education institutions and two public systems (the Kentucky Community & Technical College System and University of Wisconsin-Extension) as members.

Among the higher education institutions utilizing technology to advance competency-based education are Capella University, Southern New Hampshire University, University of Maryland University College, and Western Governors University (WGU). Founded in 1997 with initial $100,000 investments from governors of nineteen US states, WGU, a nonprofit completely online university, seeks to deliver a competency-based education at a lower cost than its for-profit competitors. In 2013 WGU enrolled 33,000 undergraduate and 10,000 graduate students from all fifty states. WGU serves high numbers of adult students, as the average age of all students is thirty-seven, and high numbers of students from low-income families, as 40 percent of undergraduate students receive a Pell grant.[81] WGU awards academic credit for students' previously held knowledge and allows students to work at their own pace, advancing in their degree program when they demonstrate course mastery. The average time to bachelor's degree completion at WGU is thirty-four months.[82] The model appears to be effective at controlling costs, as tuition at WGU is $5,800 per twelve-month year for most academic programs and has not increased since 2008.[83] WGU receives no state funding; funding comes from tuition revenue and financial contributions from partner organizations, including the Bill & Melinda Gates Foundation, Lumina Foundation, and Google.[84] Some observers[85] argue that the WGU model offers an effective approach for using technology to reconceptualize key dimensions of higher education, including whom it serves, how it delivers instruction, and how it is financed.

The Role of Technology in Solving Higher Education's Most Pressing Problems

Higher education has encouraged the development of new technologies and changed its practices to incorporate evolving technologies. Higher education has also been called to use technology to solve the pressing problems facing higher education. One current challenge is to better meet the growing need for college-educated workers,[86] while also reducing costs and ensuring high-quality learning outcomes.[87] Because of the labor-intensive nature of the traditional college model, some academics have diagnosed higher education as suffering from "cost disease."[88] Identifying effective strategies for reducing costs is paramount, given recent declines in state funding for public higher education, concerns about continued increases in tuition and fees and growth in student borrowing, and growing competition from for-profit and other nontraditional higher education providers.[89]

New technologies, including those that focus on online instructional delivery, offer the promise of increasing the production of higher education while also reducing costs and enhancing or at least maintaining quality.[90] Online courses would also seem to address constraints on the physical space available to deliver face-to-face instruction and the scheduling restrictions that often limit course enrollment for nontraditional students.[91] Recent excitement about massive open online courses (MOOCs) illustrates both the extent to which some observers are seeking a technology-based solution to improving the productivity of higher education and the challenges of utilizing new technologies to achieve this goal. Although not fundamentally changing the nature of teaching and learning, analytics, another emergent technology trend, offers a potentially effective mechanism for improving student outcomes and reducing costs.

MOOCs

Defined as full-length courses delivered over the Internet to large numbers of students at little or no charge, MOOCs build on a history of other approaches to delivering higher education at a distance.[92] Although originally conceived by Stephen Downes, George Siemens, and Dave Cormier as taking the form of an interactive seminar (the connectivist or cMOOC), recent attention in the national and higher education media has focused on the lecture-style xMOOC first launched in the fall of 2011 by Stanford University's Sebastian Thrun and Peter Norvig and advanced by such MOOC providers as Udacity, Coursera, and edX.

MOOCs offer the promise of both providing access to a high-quality education to students regardless of geographic location or ability to pay and improving productivity by teaching large numbers of learners at a fraction of the cost of traditional face-to-face instruction. Suggesting the appeal of this approach, twenty-two of the top twenty-five "best" national universities as ranked by *US News and World Report* offered at least one MOOC in 2013.[93] The *New York Times* proclaimed 2012 "the year of the MOOC."[94] MOOCs have attracted large numbers; Harvard University and MIT counted 1 million unique participants and 1.7 million total participants with 1.1 billion logged events in sixty-eight MOOCs offered between July 2012 and September 2014.[95]

MOOCs clearly represent a new "learning opportunity."[96] Regardless of their potential contributions as standalone courses, MOOCs are also a mechanism for "disseminating course tools, pedagogical innovations, and teaching modules" that may improve residential courses.[97]

Whether MOOCs create meaningful improvements in productivity and access to high-quality education will likely require greater attention to questions about low completion rates, as well as concerns about educational quality, credentialing, and financial sustainability.[98] Studies show that only between 5 percent and 12 percent of all participants complete a MOOC.[99] Completion rates have been found to be somewhat higher in the Harvard and MIT courses for those who indicated an intention to complete than for those who did not (24% versus 8%). But, suggesting that MOOCs (in their current form) have not dramatically expanded access to higher education, most (two-thirds) participants in the Harvard and MIT MOOCs already had at least a bachelor's degree.[100]

Beyond some selective colleges and universities, in 2014 only a very small fraction of the 2,800 colleges and universities responding to an annual online education survey reported having a MOOC (8%) or planning to offer a MOOC (6%).[101] Moreover, although the percentage of institutions offering a MOOC increased between 2012 and 2015 (from 3% to 8%), the share of academic leaders who agreed that MOOCs were a sustainable approach to delivering online courses declined from 28 percent in 2012 to 16 percent in 2014.[102] Further suggesting skepticism about the future role of MOOCs, the share of senior information technology officers at two-year and four-year institutions nationwide who agreed that "MOOCs offer a viable model for the effective delivery of online instruction" declined from 53 percent in the fall of 2013 to 38 percent in the fall of 2014.[103]

Despite these findings, exploration of the potential of MOOCs to deliver accessible, low-cost, high-quality credit-bearing higher education is continuing.[104] As of May 2015, a few institutions had announced plans to partner with MOOC providers like Coursera, Udacity, and edX to use MOOCs to deliver master's degree programs in business (University of Illinois at Urbana-Champaign) and computer science (Georgia Institute of Technology), as well as the first year of a bachelor's degree program (Arizona State University).[105] These endeavors have created additional questions for policy makers and campus leaders, including whether students can use financial aid to pay for these programs, the distribution of revenues to MOOC providers, mechanisms to assess content mastery in courses with "massive" enrollments, and ways to effectively engage students to promote learning.[106]

Kevin Carey, the director of education policy at the New America Foundation, projects that digital learning environments will continue to evolve so as to transform traditional higher education into the "University of Everywhere." In his vision, the University of Everywhere will enable individuals around the globe to receive the education that they need and want throughout their lifetime at a low/affordable price; completed education will be more commonly signaled by "open credentials" (e.g., badges) than by a "traditional college degree."[107] He also predicts that high-quality digital learning environments will transform the nature of academic work (with fewer people producing more and better education) and the higher education industry (with institutions that fail to evolve being driven out of the market).

In a thoughtful critique, Don Heller, dean of the College of Education at Michigan State University, outlines the negative implications that may come with an incomplete achievement of Carey's vision. Particularly worrisome is the possibility that policymakers react to Carey's vision by reducing appropriations to higher education institutions and reducing funding for student financial aid. As Heller notes, these actions would likely further stratify higher education opportunity and outcomes, with students from low-income families concentrated in "open credential" digital learning environments and students from high-income families representing even greater shares of students enrolled in four-year degree-granting institutions.[108]

Analytics

An emerging development in education technology with the potential to both improve student outcomes and reduce higher education costs is data analytics. Originated in the business sector,[109] analytics is "the use of data, statistical analysis, and explanatory and predictive models to gain insights and act on complex issues."[110]

Through analytics, higher education institutions can harness commonly collected data to answer strategic questions and improve the effectiveness of institutional practices. In a 2012 survey, 41 percent of responding institutional researchers and technology officers identified analytics as an important initiative at the department or unit level and 28 percent deemed analytics a major institutional priority.[111] Most respondents agreed that analytics were more important now than two years ago (84%) and would be even more important in the next two years (86%). To date, greater attention has been devoted to using analytics to improve student recruitment, learning, and persistence, rather than to reduce costs, optimize resource use, or improve administrative services.[112]

"Learning analytics," the educational application of data analytics, involves harnessing captured student data to "deliver personalized learning, enable adaptive pedagogies and practices, and identify learning issues in time for them to be solved."[113] Although tracing its roots to the 1990s, much of the development of learning analytics has occurred more recently. Learning analytics was not a featured technology in the annual *NMC Horizon Report* until 2011, the year the first International Conference on Learning Analytics and Knowledge convened. The first issue of the peer-reviewed *Journal of Learning Analytics* was published in 2013.[114] In 2014, the Learning Analytics Workgroup (LAW) at Stanford University released a foundational document on how to conceptualize, build, and maintain the emergent field of learning analytics.[115]

Learning analytics has been enabled by the growth of online courses and programs, hybrid courses, and MOOCs, and by the increasing sophistication of web-tracking tools. These technologies allow for the accumulation of vast data, potentially recording every interaction that a student has with online course content or a learning management system. Captured data may range from the general (such as time spent on a particular task) to more "nuanced information that can provide evidence of critical thinking, synthesis, and the depth of retention of concepts over time."[116] By mapping the learning process, learning analytics offers the potential to pinpoint precisely when a student experiences difficulties. Learning analytics may also be used to identify best practices for improving learning outcomes, particularly for learners with different characteristics and learning needs. Realizing the potential benefits of analytics will require higher education institutions to not only collect "big data," but also design data collection protocols that provide the types of data needed to inform understanding of effective instructional practices.[117]

The Predictive Analytics Reporting (PAR) Framework, a nonprofit collaborative overseen by the Western Interstate Commission for Higher Education (WICHE), is one example of a potentially productive application of analytics. According to its website, as of January 2015, the PAR Framework had accumulated 1.7 million de-identified student records and 18 million course-level records from thirty-three higher education institutions and systems. The PAR Framework is designed to mine these large-scale data to provide member institutions with performance benchmarks and predictors of academic risk and student success. Member institutions are expected to be able to use this information to develop appropriate and targeted intervention services that improve student outcomes.

Barriers that Influence the Adoption of New Technologies

Perhaps because higher education is in the business of knowledge creation, stakeholders assume that higher education will use the most current technologies in core operations and functions. The Spellings Commission on the Future of Higher Education clearly articulated this assumption when it recommended that "America's colleges and universities embrace a culture of continuous innovation and quality improvement. We urge these institutions to develop new pedagogies, curricula and technologies to improve learning, particularly in the areas of science and mathematics."[118]

Technological innovation is occurring. But, even when associated with positive desired outcomes, higher education has experienced challenges bringing innovations to scale.[119] For example, one well-regarded approach to leveraging information technology to enhance student-learning outcomes and reduce the cost of higher education is the program and course redesign developed by the independent, not-for-profit, National Center for Academic Transformation (NCAT).[120] With $8.8 million in support from the Pew Charitable Trusts, NCAT developed the Program in Course Redesign (PCR). In the PCR project, NCAT worked with thirty colleges and universities from 1999 to 2004 to use instructional technology to deliver courses at lower cost and with at least comparable student learning and retention outcomes. Key components of the PCR model included "online tutorials, Web-based discussion groups, on-demand support and group activities, and automated assessment of class exercises, quizzes, and tests."[121] NCAT reports positive outcomes at all thirty of the original partner institutions, with cost savings ranging from 20 percent to 77 percent or a total savings of $3 million. NCAT has built on these initial efforts with funding from the Fund for the Improvement of Postsecondary Education (FIPSE), Bill & Melinda Gates Foundation, and several state systems of higher education (e.g., Arizona Board of Regents, State University of New York, University System of Maryland) to redesign other courses. NCAT reports that, of the 156 redesign projects completed to date, 72 percent have demonstrated improved student learning outcomes (with the remainder demonstrating comparable outcomes) and all have reduced instructional costs (with reductions ranging from 5% to 81%). NCAT also self-reports other positive outcomes, including higher course completion and program retention rates as well as student and faculty satisfaction.[122]

These improvements in instructional productivity have occurred largely at the level of the individual course, rather than at the department, university, or system levels.[123] Course-level improvements in instructional productivity tend to reflect an "incremental" approach to change[124] or a "sustaining innovation,"[125] as opposed to a "disruptive innovation."[126]

Unlike other innovations, disruptive innovation changes "the underlying structure of higher education" and involves more than just "simply operating within a tightened budget."[127] Christensen and colleagues define disruptive innovation as "the process by which a sector that has previously served only a limited few because its products and services were complicated, expensive, and inaccessible, is transformed into one whose products and services are simple, affordable, and convenient and serves many no matter their wealth or expertise."[128]

A sustaining innovation may improve an organization's performance and enhance the quality of products or services produced, but a disrupting innovation changes the nature of the product or service and attracts "a new population of customers."[129] A disruptive innovation is associated with fundamental changes in higher education—"its processes, where it happens, what its goals are."[130] Disruptive technologies typically begin at the margins, are initially expensive to produce, and are slow in gaining widespread appeal.[131]

Many forces restrict the widespread adoption and use of online learning and other technological innovation.[132] Although potentially creating many benefits, disruptive innovation often has economic and noneconomic costs. Some of the noneconomic costs are cultural, as disruptive innovation "threatens our security and challenges our traditions."[133] Other forces are structural, including constraints imposed by federal regulations, accreditation requirements, and internal institutional course approval processes.[134] Disruptive innovation may also be resisted because of potentially worrisome implications of technological innovation for access, cost, quality of education produced, and faculty, as well as for the well-being of both individual higher education institutions and the nation's higher education system as a whole.

Can Technological Innovation Reduce Costs?

The implications of technology for higher education costs are ambiguous. Some assert that online learning and other technological innovation can create considerable reductions in instructional costs.[135] Others suggest that by enabling institutions to expand into previously untapped markets, online instruction may provide a new source of revenue.[136]

At the same time, others argue that online instructional delivery costs more, not less, than traditional face-to-face education.[137] Offering instruction online is more complex than simply uploading materials into a course management system.[138] Developing and delivering online learning may also generate new costs.[139] The initial financial resources required to develop online courses and provide the necessary technological infrastructure (e.g., a learning management system) may be sizeable, but decrease over time as more online courses are replicated.[140]

More than half of chief academic officers believe that it is likely (36%) or very likely (25%) that online courses will be substantially less expensive than face-to-face courses. Yet technological innovation—including both use of technology in instructional delivery and data analytics—has start-up as well as long-term and ongoing costs. Faculty and staff will likely regularly require assistance and training. IT staff will be required to provide ongoing system maintenance and technical assistance, and student support staff will be needed to manage online enrollment and troubleshoot technology-related difficulties.[141] Rapidly changing technologies will likely require regular hardware and software license upgrades as well.[142]

Can Technological Innovation Maintain or Improve Quality?

One force limiting the growth of online education is continued uncertainty about educational quality and student learning outcomes. Over time, perceptions about the quality of online education have improved. About 74 percent of academic leaders responding to the 2015 Babson Survey Research Group's annual survey rated learning outcomes in online courses as the same or superior to learning outcomes in face-to-face courses. By comparison, when the survey began in 2002, 43 percent of chief academic officers believed that learning outcomes in online education were inferior to face-to-face education.[143]

Particularly important to the future of online education are the views of faculty. Only 9 percent of faculty responding to a fall 2014 survey strongly agreed (and only an additional 26 percent agreed) that online courses could produce student learning outcomes that were at least as good as those produced in face-to-face instruction.[144] Responding faculty were especially skeptical about whether online courses could provide high-quality interaction between faculty and students inside and outside of the courses, attention to at-risk students, and answers to student questions.[145] Only 28 percent of chief academic officers responding to the Babson Group's fall 2014 survey reported believing that their faculty "accept the value and legitimacy of online education."[146] Although the percentage has fluctuated somewhat over time, this percentage is virtually the same as it was in the fall of 2002 (27.6%).

Available research comparing learning outcomes for online and face-to-face instruction shows mixed results. Much of the research comparing outcomes for students in traditional face-to-face courses, online courses, and blended courses has noteworthy methodological limitations.[147] With funding from the US Department of Education, Barbara Means and colleagues conducted a comprehensive meta-analysis of 46 studies that used experimental or quasi-experimental research designs to compare student-learning outcomes in online and face-to-face instruction in courses from pre-college through graduate school. Defining online education as "learning that takes place partially or entirely over the Internet," the authors found that, on average, both blended learning and purely online learning models produced better student learning outcomes than face-to-face instructional models; average outcomes were highest for blended learning.[148] But some individual studies showed face-to-face instruction as producing better student learning outcomes. In a more recent review of 30 studies of online learning at higher education institutions, Lack concluded that results were inconclusive, noting that there is "little, if any, evidence to suggest that online or hybrid learning, on average, is more or less effective than face-to-face learning."[149] Lack, however, used less rigorous criteria for identifying included studies than did Means and colleagues.

Will Technological Innovation Be Embraced by Faculty?

Technological innovation will not increase degree production, reduce higher education costs, or enhance quality if faculty do not embrace and adopt the innovation. Online education has tended to expand in an ad hoc manner based on intrepid faculty members' interests rather than based on centralized administrative planning.[150] Faculty tend to "teach as they were taught,"[151] and may believe that online learning will limit interactions with students and/or enable institutions to cut faculty jobs.[152]

Institutional leadership and strategic campus planning will likely be required to counter faculty apathy (at best) and faculty resistance (at worst) to new technologies and thereby maximize any potential benefits.[153] Faculty resistance is one force that has limited the more widespread adoption of MOOCs on some campuses, including San Jose State and Amherst College.[154] The potential benefits of analytics also depend on faculty; the insights produced by analytics will not be incorporated into higher education practices if faculty (and administrators) mistrust institutional data and analysis or do not understand how data can be used to inform decisions.[155]

Providing training and ongoing assistance to faculty and staff is one strategy for encouraging faculty to use new technologies.[156] Reports from both faculty as well as senior technology officers indicate that many institutions now provide limited technology-related training to faculty.[157] Only a minority (28%) of senior information technology officers at two-year and four-year colleges nationwide reported in the fall of 2014 that current IT training for faculty was "excellent."[158] Most respondents (81%) reported that assisting faculty with the integration of information technology into instruction would be a high priority in the next two to three years.[159]

Another potential approach is to incentivize faculty and staff to engage in the training and adoption of new technologies.[160] Prevailing faculty reward structures tend to emphasize research productivity, providing little incentive for faculty to expend time and effort learning and incorporating new teaching practices.[161] Only 1 percent of faculty responding to a fall 2014 survey reported that their institution rewarded teaching with technology in tenure and promotion decisions.[162]

Faculty may also resist technological innovation that is perceived to threaten their autonomy or limit their ability to design a course, customize course materials, and determine course sequencing.[163] Online courses tend to be developed and implemented not by an individual faculty member working independently (as in a traditional face-to-face course) but by an instructional team that includes the faculty member as well as instructional designers and IT professionals. In short, online instruction tends to recast the traditional workflow model into a more horizontal, collaborative model.[164] This expansion of personnel has implications for faculty autonomy, as well as other complex and often contentious issues like intellectual property rights, shared governance, and compensation.[165]

Concluding Note

Technology is an ever-present and ever-changing societal force that both influences and is influenced by higher education. Higher education will certainly continue to change in response to technological innovation. Whether these changes create more than incremental improvements in access, cost, and quality—and fundamentally increase access to high-quality higher education at lower cost—is yet to be seen.[166] Higher education institutions must not only be willing to change, but must also supply the leadership, financial resources, training, and incentives necessary for technological innovation to stimulate institution-wide reform and reduce the economic and non-economic costs of the reform.

Technology is a set of tools; higher education faculty, administrators, and policymakers will determine whether and how available tools are used to advance higher education productivity and improve other valued outcomes.

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