

# Connecting the Dots

## New Technology-Based Models for Postsecondary Learning

Chris Dede, editor

Advances in technology and in knowledge about expertise, learning, and assessment have the potential to reshape higher education, as well as the many other forms of learning past matriculation from high school. In the next decade, higher education, military and workplace training, and professional development should all transform to exploit the opportunities of a new era, leveraging models based on emerging technologies that can make learning more efficient and possibly improve student support, all at lower cost for a broader range of learners. That said, potential risks must be managed, including the disruption of established delivery economics in our current learning institutions, the variable quality of the learning outcomes these new models offer today, and the technical and conceptual challenges of better understanding how to design, develop, and implement innovative capabilities in ways that reliably deliver on their promise.



## Reconceptualizing Postsecondary Learning

New media, insights from research, and alterations in organizational structures are changing long-standing assumptions that have shaped higher education. Shifts now occurring affect both instructional objectives and instructional processes.

### Instructional Objectives

■ *Moving from thinking about expertise as something an expert “knows” and can articulate to thinking about expertise as a complex mix of tacit (i.e., non-conscious) and conscious competencies.* This evolution has major consequences both in how we identify the critical competencies that experts exhibit and in how we design instruction to reach those competencies. Simply asking experts to “teach” whatever comes to mind, whether in an online format available to millions or in their own classrooms, is not enough to effi-

ciently bring many students to expert performance levels.

■ *Moving from knowledge and skills localized in a student’s mind to distributed understandings and performances.* Our understanding of expertise has expanded beyond something “stored in the head” and documented by its retrieval in sequestered testing. Expertise now includes a collection of elements accessible via technologies (e.g., mobile devices, search engines, and augmented reality) that enable finding necessary information rather than remembering it. Mastery involves decisions about when to make use of such resources, as well as when these are not sufficient. Understanding how to apply distributed knowledge and skills in real-world and novel contexts therefore requires demonstrations via sophisticated, authentic performances adapting to complex situations, rather than traditional rote recall of a small amount of

what experts comprehend and do in routine situations. In medicine, this distinction is exemplified by the distinction between lectures and “grand rounds.”

■ *Moving from a focus on memorizing and applying facts, simple concepts, and straightforward procedures to “higher-level” conceptual and analytical capabilities deployed adaptively in diverse contexts.* By increasing the accessibility and affordability of experiences with higher-level problem-solving, complex decision-making, and learner-based experimentation and exploration, technology-based instruction and practice substantially increase opportunities for learners to focus their attention on the conceptual and analytical capabilities that underlie the deep understanding, retention, and transfer of learning needed to deal with lifelong, real-world applications. These capabilities are key to the development of expertise and the

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promotion of innovation—which, in turn, lead to an expanding economy prepared to meet the rapidly evolving science and technology challenges of the future.

- *Moving from a primary focus on the conceptual and procedural aspects of learner competencies that are often described as “cognitive,” to an equal emphasis on complementary aspects of learner competencies, “non-cognitive factors,” which are instrumental to successful postsecondary learning, work, and citizenship.* Extensive research from social and developmental psychology has documented how learner orientations such as persistence/grit, engagement, “mindset” about intelligence (as either improvable through effort or as a nonmalleable personal attribute), stereotype threat, and related constructs are consequential for learning.

#### Instructional Processes

- *Moving from time-based models of schooling to competency-based learning.* Research on learning shows that students critically differ from one another in terms of their unique, historically constructed, long-term memories and their personal goals and motivation, with the consequence that the “same” processes are experienced differently by individual learners. The “taught curriculum” differs from the “learned curriculum.” Lock-step classroom instruction for courses cannot take into account the vast divergences in prior learning, the differences among individuals, and the varying time needed to acquire competencies. Increasingly, technologies for learning enable adaptive learning experiences that are responsive to the uniqueness of each student as an individual, providing the opportunity in the calendar time available to achieve targeted competencies as well to surge beyond to “all the student can be.” Competency-based, personalized instruction made affordable and accessible through technology can enable all learners to suc-

ceed, in many cases more quickly and at lower cost, by providing whatever amount of support is needed to attain mastery—anyplace, anytime—with immediate certification or credentialing when this occurs.

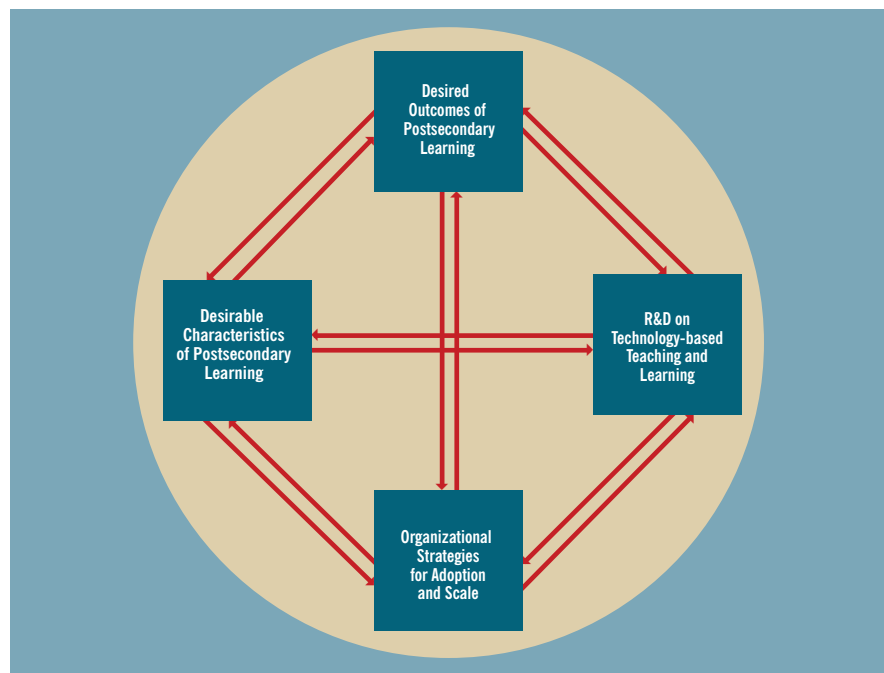
- *Moving from a few providers to many sources of accredited learning.* The disintermediation and distribution of learning made possible through technology has vastly increased the range of providers, innovative business models, and new marketplaces for services. This is leading to substantial shifts in the attitudes of both students and employers toward institutional credentialing. This disintermediation, with its increased agility for adapting not only to learners but also to the needs of the workforce, leads to an even sharper focus on exactly what competencies truly predict success in a domain after leaving a learning environment—and what performance demonstrations provide evidence of successful education and training.
- *Moving from educational improvement based on occasional evaluations to continuous analytics providing feedback across multiple providers.* Aggregated data-streams from participants in learning activities provide mechanisms for continuous improvement and research via diagnostic analytics at large scale. This requires, however, that we develop behavior and success-at-scale assessments that are reliable and valid for each individual, adding up to usable evidence for future accomplishments in the learners’ domains of interest. This advance also creates pressure to have more generalized guidelines for what constitutes a “good enough” pilot or trial (especially at scale, not just in laboratory settings), as well as “good enough” measures for predictive variables.
- *Moving away from a conception of technologies in education and training as explicitly “educational technologies.”*

Researchers are increasingly recognizing that learners and instructors are using a full spectrum of information and communication technologies beyond learning management systems, courseware, tutors, and the like. As “bricoleurs,” these learners and instructors are taking what they need from the broad palette of tools available in their everyday experiences—whether social networks, cloud computing tools, mobile apps, physical meet-ups, or other emerging resources.

A useful construct for understanding these shifts in today’s environment is *connected learning*. *Online learning* or *e-learning* are terms that may unnecessarily limit what is possible with information technology. Both have roots in original conceptions of distance education, where the objective was to port classroom-style learning to off-campus students through an alternative delivery mechanism, whether via the postal service, cable television networks, or the Internet. But what happens when the metaphor is changed from “the information age” to connected “learning in the networked world”?<sup>1</sup> Mimi Ito and her colleagues note that connected learning “is *socially embedded, interest-driven, and oriented toward educational, economic, or political opportunity*. Connected learning is realized when a young person is able

**This disintermediation leads to an even sharper focus on exactly what competencies truly predict success in a domain after leaving a learning environment.**

to pursue a personal interest or passion with the support of friends and caring adults, and is in turn able to link this learning and interest to academic achievement, career success or civic engagement. This model is based on evidence that the most resilient, adaptive, and effective learning involves

**FIGURE 1. FRAMEWORK FOR POSTSECONDARY LEARNING**

individual interest as well as social support to overcome adversity and provide recognition.”<sup>2</sup>

To explore connected learning, educators must continue their work linking schooling to interdisciplinary problems and collaboration beyond classrooms and campuses. Although some research provides insights about connected learning, further exploration is needed on large-scale collaborative and connected environments. These environments should transcend K–12 and higher education to include the workplace and citizens. There is merit to continuing the

exploration of how to engage learners as “prosumers” in generative scholarship, in which they help build the knowledge of the field and use the tools of the profession to draw their own conclusions. Of course, learning encompasses more than content: it involves learner empathy, support, motivation, persistence, and more. When learning is connected, it forms pathways; one activity feeds forward to another. Learners are not often engaged in unrelated activities—they eventuate from their identity and intentionality as they pursue their interests. Nor are they in the dark about the

progress they have made, the improvements they need, or what comes next. With connected learning, the focus is on continuing pathways, not gates or gate-keeping. The point is to connect the dots and to connect learning with life.

### A Framework for Understanding Postsecondary Learning

In a January 2013 Computing Research Association Workshop sponsored by the National Science Foundation (NSF), the fifteen participants developed a framework for interrelating the various dimensions of postsecondary learning. Figure 1 provides an overview of this framework. (For reasons of space, this article will not elaborate on the R&D aspect of the framework.)<sup>3</sup>

#### *Desired Outcomes of Postsecondary Learning*

The various outcomes that students, employers, and society seek from postsecondary learning can be grouped into four categories:

1. *Advanced knowledge and skills manifested as understandings and performances.* As described in the report *Education for Life and Work*, cognitive, intrapersonal, and interpersonal dimensions of advanced knowledge and skills are developed in tandem.<sup>4</sup> Table 1 categorizes the knowledge and skills according to dimension. Mastery involves understanding how to apply advanced knowledge and skills in real-world contexts—for which all three dimensions are important—and demonstrating proficiency via effective, authentic performances. What makes mastery even more complex is how much of the decision-making and task completion associated with a complex performance becomes tacit through repeated practice. Thus, what underlies proficiency is largely hidden from view, making an accurate description of mastery challenging to fully articulate.
2. *Support for personal development, identity evolution, and socialization.* In the rapidly changing 21st century, many forms of

**TABLE 1. DIMENSIONS OF ADVANCED KNOWLEDGE AND SKILLS**

COGNITIVE OUTCOMES	INTRAPERSONAL OUTCOMES	INTERPERSONAL OUTCOMES
Cognitive processes and strategies	Intellectual openness	Teamwork and collaboration
Knowledge	Work ethic and conscientiousness	Leadership
Creativity	Positive core self-evaluation	Communication
Critical thinking	Metacognition	Responsibility
Information literacy	Flexibility	Conflict resolution
Reasoning	Initiative	
Innovation	Appreciation of diversity	

postsecondary learning include opportunities (a) to enhance personal characteristics, such as leadership and collaboration, (b) to evolve identity in assuming or shifting occupational roles, and (c) to be socialized into the norms and cultures of workplaces, fields, and multinational contexts.

3. *Increased capacity for better opportunities in work and life.* Effective educational models are emerging that blend academic instruction with workplace experience, including remote internships and immersive simulated apprenticeships. These models are enabling seamless transitions between education and employment, ongoing occupational support and development, and informal life-wide and lifelong learning.
4. *Social capital for further learning.* The development of social capital (e.g., networks of people who provide mentoring) contributes to furthering learning and its associated productivities beyond the initial educational experience, as well as to supporting the other three outcomes described above.



Individual higher education institutions might seek to offer one or more of these four categories of outcomes. Collectively, all institutions—forming the aggregate system of postsecondary learning—should provide access to all four categories of desired outcomes.

#### *Desirable Characteristics of Postsecondary Learning*

Higher education and other postsecondary learning organizations that are working, individually and collectively, to

achieve these four categories of desired outcomes should strive to exhibit the following characteristics:

- *Serve a wide range of learners.* As massively open online courses (MOOCs) are demonstrating, new models of technology-based teaching and learning can reach learners worldwide by using a variety of delivery options and by relaxing traditional constraints on fees and enrollment.
- *Provide a good return on investment for learners and for society.* An important goal for postsecondary education is providing quality learning opportunities with high rates of retention and success in building knowledge and skills valued by learners, useful for society, and providing economic return. The new technology-based learning experiences described in this article show promise of offering these benefits at lower costs than traditional approaches to instruction and training, in a manner efficient for learners in terms of time and access.
- *Gain self-improvement via research and continual feedback.* New technologies provide mechanisms to collect and analyze massive amounts of detailed data about every aspect of the learning experience, as well as to collect ongoing diagnostic assessments of a learner's engagement and understanding that could be used formatively to guide subsequent instruction and learning. This can improve both efficiency and effectiveness for each individual's learning, as well as allowing overall, evidence-based evolution of learning experiences, in part through such mechanisms as A/B experiments that enable refining instruction in terms of what works when for whom.

Individual higher education institutions might have one or more of these characteristics. Collectively, all institutions—forming the aggregate system of postsecondary learning—should have all of these characteristics.

#### *Organizational Strategies for Adoption and Scale*

The speed and scope with which the potential benefits of innovations in postsecondary learning are realized will depend on the sophistication of the strategies used for adoption and scaling. The challenges associated with spreading and deepening transformational educational innovations have received increasing attention from researchers.<sup>5</sup> Institutions need to do the following:

- *Build and use authentic assessments based on outcome objectives.* Developers of postsecondary learning environments should clearly define the nature of the competencies that students will develop over time, with instructional guidance, and how this knowledge links to expert performance, as well as specifying the forms of evidence necessary to monitor student progress and outcomes. Such work, much of which is exemplified by redesign projects in the STEM disciplines, involves applying ideas such as “backwards design”<sup>6</sup> and constructive alignment<sup>7</sup> for course and curriculum design and “evidence-centered design”<sup>8</sup> for associated assessment development.
- *Select initial innovations carefully so that strong models of learning are implemented well.* Too often, educational innovations are dismissed as ineffective because early implementations were suboptimally conducted and were based on marginal models of teaching and learning (such as passively viewing video-lectures). To minimize this problem, institutions should base their initial efforts in using a technology-based innovation on strong models of (inter)active learning, should involve effective instructors who are willing to reconfigure their teaching to new forms of delivery, should use implementation-fidelity measures to compare what was intended to be experienced with what was actually experienced, and should utilize thorough planning for broad



implementation rather than rushing to be first-to-market.

- *Emphasize convivial tools and user-friendly interfaces.* In the digital market, the devices and software that succeed are based on transparent interfaces requiring little cognitive overhead from users. Design for simplicity and transparency is central in developing technology-based learning experiences that can scale to broad audiences with differing levels of digital sophistication.
- *Study the design and adoption strategies for effective educational media that have scaled.* The programming languages Scratch and LOGO are now ubiquitous in learning about computer science, but decades of design-based research were required to develop them to their current level of scalability. Lessons learned from these and other educational media that have achieved widespread acceptance and impact can inform the next generation of technology-based educational innovations.
- *Accomplish tasks that instructors and institutions are happy to relinquish.* Uptake of technology-based models in postsecondary learning will occur most rapidly for innovations that accomplish the tasks that instructors and institutions now find onerous. For example, effective technology-based strategies that aid students who are struggling to succeed with mainstream curricular offerings (such as remedial mathematics) are likely to be quickly adopted and scaled.
- *Use organizational-development strategies for changing the culture.* Many postsecondary educational institutions have common challenges in culture (e.g., a “not invented here” attitude about curriculum, instructors who are phobic about or dismissive of technology-based instruction, or a belief that online learning is necessarily impersonal). Increasing effective adoption and scale requires professional and organizational development initiatives to alter these misconceptions and change the institutional culture.

### An Illustrative Model of Technology-Based Teaching and Learning

The following example of a technology-based teaching and learning model illustrates these general principles for desired outcomes, desirable characteristics, and organizational strategies.

#### Type of Pedagogy

The model incorporates immersive virtual simulations of internships and apprenticeships

#### Description of the Model

A student, Susan, enters the institutional portal for the initial session of her learning experience about the methods of ecosystems science. The learning objectives for this experience are to diagnose the problems of various simulated environments using the knowledge and methods of ecosystems science, based on a cognitive task analysis of the expert processes of ecosystem scientists. Over the next month, 8,000 students are taking this learning experience, which is based on parts of a college course that is reviewed every year against what objectively high-quality experts in this field decide and do. Susan has completed a questionnaire that generated her learning profile, has done her readings and video preparations, and has passed the initial assessment.

Susan was pre-assigned three virtual teammates with complementary knowledge and skills and similar schedules for access. Each of the four has his/her own individualized, practice experience as well, to ensure that they all master the basic knowledge components, but the four must coordinate their involvement so as to work as a stable team throughout their various learning sessions on specific projects. The primary method of learning is immersion in virtual worlds that simulate ecosystems problems. As a secondary method of learning, Susan and her teammates have access to a few sessions of edited video-clips from the

college course and a virtual study group of sixteen students in four teams, with each team experiencing different simulated ecosystems.

After initial skill-building based on diagnostics of what the students have already mastered, the curriculum is inquiry-based, with the project environments and questions moving from relatively straightforward to increasingly complex as teams demonstrate progress: students investigate research questions by exploring immersive digital ecosystems,<sup>9</sup> with each team member having a role based on a different area of expertise (e.g., botanist, microscopic specialist). In these ecosystems, the team interacts with Animated Pedagogical Agents who use

### Immersive virtual environments enable productively transcending real-world limits on social interaction.

Transformed Social Interactions (both are discussed further below). The members of each team work collaboratively to analyze their combined data and understand the ecosystem interrelationships, rotating roles (which may require some individual practice and feedback during the transition) as they move through different simulated ecosystems. As a summative assessment, each module culminates with the team creating a causal model of the ecosystem, supported by data and theory; this is scored by automated pattern-matching algorithms.

Immersive virtual environments enable productively transcending real-world limits on social interaction.<sup>10</sup> As one example of how Transformed Social Interaction (TSI) is used, since eye gaze influences persuasion, in these virtual ecosystems digital mentors maintain eye contact with every digital apprentice at the same time. This is possible because all the students see the virtual world from their own computer display, and these versions of reality need not be

congruent. Another TSI feature is “identity capture”: the digital mentor’s face is morphed so as to unobtrusively make that person look similar to each student, because students whose teachers resemble them pay more attention. Likewise, students interacting with virtual agents who look just like them and who model behaviors for the students to master have improved learning outcomes; this feature is used as well.

The unobtrusive, real-time assessments used to provide formative feedback include the following:

- *Capturing exploratory paths.* The paths that a student takes in exploring a virtual world to determine the contextual situation, identify anomalies, and collect data related to a hypothesis for the causes of an anomaly are an important predictor of the student’s understandings about scientific inquiry.

- *Analyzing usage of guidance systems.* Gathering data on students’ use of an interwoven individualized guidance system (both before and during projects), which messages they viewed, where they were in the immersive simulation when they viewed them, and what actions they took subsequent to viewing a given guidance message provides diagnostic insights that can aid instruction.

- *Interacting with Animated Pedagogical Agents (APAs).* APAs are lifelike autonomous characters that co-habit learning environments with students to create rich, face-to-face learning interactions.<sup>11</sup> The trajectory over time of questions that students ask of an APA is diagnostic: typically learners will ask for information that they do not know but that they see as having value. This can help reveal a student’s thought processes and methods of

knowledge acquisition and should allow further personalization of learning topics that an individual student might need to master. Also, APAs scattered throughout an immersive authentic simulation can collect diagnostic information in various ways; for example, the APA can request a student to summarize what he or she has found so far.

- *Documenting progress and transfer in similar settings.* Shifting a student to a similar but not identical environment in which he or she must identify a problem (earlier in the curriculum) or resolve a problem (later in the curriculum) can provide insights into a student’s progress and can aid transfer. Further, centering these benchmarking assessments on learners’ common misconceptions, and then immediately conveying the results to students, can prompt “aha” moments

that help to synthesize new levels of understanding.

- *Attaining “powers” through accomplishments.* Like leveling up in games, students can attain new powers by reaching a threshold of experiences and accomplishments. These new capabilities document team achievements, promote engagement, facilitate learning, and offer additional opportunities for interwoven assessment.<sup>12</sup>

All of these types of assessment are based on authentic actions in rich simulated contexts. In addition, A/B experiments are continuously conducted by the designers to improve the learning experience. These include varying the complexity of the simulated environments, trying different forms of unobtrusive assessments, and changing the amount of TSIs and APAs utilized.

Immersive virtual simulations of internships and apprenticeships empower aspects of the proposed framework for understanding postsecondary learning in the following ways: lower cost; broader initial access and potential for success; good return on investment; increased capacity for better opportunities in life; advanced knowledge and skills; authentic assessment; and help for faculty and organizations in linking education to work. The scenario provides a description of just one out of many possible technology-based teaching and learning models that exemplify desired outcomes, desirable characteristics, and organizational strategies for adoption and scale.

### Why Educational Leaders Should Take These Ideas Seriously

Most forms of postsecondary learning are experiencing disruptive change. The external environment is seriously questioning the costs, accountabilities, and resulting value of much of the higher-education enterprise. Workplace training is given lip service, but similar questions arise when budgets are scrutinized. In both cases, the rise of “post-traditional learners”—those who are older, are

first-generation, attend part-time, or are unprepared for college and other forms of postsecondary learning—is catalyzing change, as are new institutional models that promise to meet their needs.

In particular, the advent of massive open online courses (MOOCs) has inverted the funnel of all postsecondary learning institutions. Rather than needing to pass through a narrowing admissions filter to gain access to educational opportunities, potential learners worldwide can now freely access high-quality, interactive, certification-granting programs, with only their ability to master the material in a timely fashion limiting their experience. The computational infrastructure that supports massive distribution of postsecondary learning worldwide, the assessment tools that enable hundreds of thousands of participants to be measured and to receive immediate, individualized diagnostic feedback, the social media environments that enable group discussion on massive scales, and the growing suite of simulation and interaction tools are combining to create a new, ubiquitous infrastructure. Whether used for global, distributed learning or applied to augment residential-based experiences, these new models of instruction are dramatically changing the face of postsecondary learning. This infrastructure challenges the roles of synchronous classroom experiences and the value of campus life in learning, offers new options for assessment and personalized exploration, provides opportunities to rapidly and dramatically change how we teach, based on data analytics at massive scales, and is disrupting traditional financial models for both education and training.

Leaders in education and training are faced with important decisions in the near future. Rather than ignoring technology, which may eventually overwhelm their current institutional practices (with the metaphor of a “tsunami” often offered), they must ask: How can technology enable an evolution to more efficient and effective pedagogies? What

tools and techniques—whether technology, cognition, analytics, simulation, or collaboration—ensure that learning is grounded in the most sophisticated strategies available? How will technology enable decision-makers to achieve more readily, and with higher instructional effectiveness, the economies now sought through the use of large classroom lectures? How might the certifications



offered by online technology be authenticated and validated? How might technology help ensure the fiscal viability of instruction in the highly specialized areas of learning sought by limited numbers of students?

The challenges involved transcend the impact of technology on pedagogy, faculty time, or the quality of institutional learning experience. New business models are emerging, with selected functions being outsourced to external providers or “in-sourced” as for-profit ventures partner with traditional institutions to create programs financed through a share of future tuition. And, as new models promise lower costs, institutions are being challenged to return more of the “profit” from lower-division or online courses to the students or the taxpayers. Ultimately, the changes affect more than individual institutions; the changes will likely reshape the entire ecology of postsecondary learning. As in any ecological disruption, not all species will survive: new niches in the ecosystem will be filled by species better suited to new conditions.

Questions need to be asked about the best uses and contributions of learning technologies and about how those technologies may influence the business



and financial model of an institution, its pedagogical and curricular infrastructure, and its professional development strategies.



### **Why Faculty Members and Instructors Should Take These Ideas Seriously**

New technology-based models of learning have provided faculty with a variety of educational tools, but they have also generated a host of concerns. Both the popular and the academic press have speculated wildly about how MOOCs, in particular, will affect the organization and economic base of higher education, the structure of the curriculum, and the professional identity of the faculty. Which colleges and universities will

even continue to exist? As noted above, although the exact shape and character of the academy in a post-MOOC world is impossible to predict, it is likely, as both history and current events indicate, that post-secondary education will be changed in significant ways. Those effects will probably be more nuanced and more complex than predicted by either the promoters or the critics of MOOCs, which are an early, naive form of the models that will eventually emerge. Thus, it is incumbent upon faculty and instructors to educate themselves about research on how expertise and learning actually work (as opposed to the informal ideas that most faculty members have used to frame their instruction so far), the opportunities educational technologies afford, how those technologies can help improve the economics of delivery and the likelihood of student success, and what collateral changes may occur in their wake.

These models may enable post-secondary education and training institutions to provide their students with more of the benefits now found primarily in graduate study, such as guided problem-solving and connected, personalized work with experts and distinguished faculty who explore and learn in the company of their students. Faculty and trainers may find it useful to explore the tools, techniques, and processes of guiding experiences in authentic, “situated,” real-world environments. Much of the low-level drudgery of teaching may be assumed by technology: tailoring standardized learning environments to students’ needs and particular instructional objectives and providing frequent diagnostic assessments of students’ progress. Technology may also help to fill the gap between the quasi-conscious, almost reflexive techniques used by experts in problem-solving, experimentation, and

exploration and the basic enabling steps needed by their students to achieve equivalent levels of competence.

That said, large gaps exist in our understanding of educational practices with these technologies. Action-based research can give faculty and instructors a clearer picture of the future of postsecondary education and training, the institutions that provide it, and how to undertake the critical task of preparing learners for their personal future and that of their nation and global society.

### **Why Providers of IT/Technology Infrastructure Should Take These Ideas Seriously**

Providers of IT/technology infrastructure (aka “cyberinfrastructure”) services should pay attention because the services they provide constitute an essential platform for what is envisioned here.

Cyberinfrastructure includes technology together with the human and organizational resources to create and deliver services. Cyberinfrastructure enables the creation of learning ecosystems that can radically relax constraints of geography, time, and access—including access to new resources for learning. Much of the disruption and opportunity premised here is a consequence of the continual expansion in both scale and function of cyberinfrastructure.

Understanding and realizing the potentials highlighted here will require participatory design and cooperation among the providers of technology, learning and technology researchers, administrative leaders, and instructors and learners. We all need to better understand the mechanisms of new technology-based models for enhancing learning and teaching, and the user community needs to better

understand the potential of these emerging technologies to enhance learning and aid instruction. A “waterfall” model for cyberinfrastructure provisioning will simply not work. Both the nature of cyberinfrastructure provisioning and the pedagogies enabled by that cyberinfrastructure are in rapid flux. Although many educational organizations provide these services locally, this scenario is being augmented and may be overtaken by remote cloud services together with personally owned, sensor-enabled, mobile Internet access devices.

At the same time that the potential for meaningful use of cyberinfrastructure to support education has never been greater, and the possible modes for providing services are increasing, most educational institutions are under unprecedented financial stress and growing public concern about higher education

affordability and even relevance. In response to this, the providers of cyberinfrastructure services for educational organizations must rationalize and reduce the cost of providing the current generation of services while also providing leadership for evolving to the next, probably cloud-based generation of services. To realize the full potential of this shift, providers must be significant consumers of research on how learning works, as well as being participants in strategic planning processes for the future of postsecondary educational organizations. Providers must also be able to convince executives who have budgetary control that wise investments are necessary to explore and adopt the new services critical to thriving in their mission. At a minimum,

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educational organizations may retain the savings from rationalization to reinvest in the next generation of services. It is not easy to decide exactly what these investments should be: we need to adopt an attitude of exploration and experimentation, with a lean startup model of fast trials and failures in order to rapidly learn and improve while at the same time not disrupting the current critical services.

This framework provides some of the necessary vision and contributes to increasing the urgency for the strategic planning and action (e.g., financial investment, policy shifts, organizational changes) that is necessary to move toward a bright future.

## Conclusion

Future models for higher education and postsecondary learning may take many forms. For the relatively uninitiated, a first step in preparing for transformation might be simply to learn the vocabulary—MOOCs, wikis, social media, back-channel, learning analytics, peer

assessment—and the other catch-phrases and acronyms that are part of the growing lexicon of educational technology. Faculty and other instructors who are already using technology, or who plan to use it soon, should examine ways in which the field is identifying best practices around the use of specific tools and should familiarize themselves with what is now known about how learning actually works (and doesn't work). New models for technology-enhanced education are being designed at an ever-increasing pace, and instructors at all levels need to educate themselves about those innovations and need to learn how to identify which are helping learners and which are not. Otherwise, new models—effective and ineffective—may appear in their organizations with the potential to rapidly scale before faculty and instructors are prepared to deal with them constructively.

The primary barriers to altering curricular, pedagogical, and assessment practices so as to move toward the transformative vision of postsecondary learning advocated here are not conceptual, technical, or economic. The primary barriers are psychological, political, and cultural. We now have all the means necessary to implement effective educational models that can prepare all students for a future very different from the immediate past. Whether we have the professional commitment and the societal will to actualize such a vision remains to be seen. ■

## Notes

The views expressed in this article are those of the workshop participants and are not official positions of the National Science Foundation or the Computing Research Association. For the original workshop report, see "New Technology-Based Models for Postsecondary Learning: Conceptual Frameworks and Research Agendas," Computing Research Association (CRA), April 2013, <http://cra.org/resources/research-issues/>.

1. National Science Foundation, *Fostering Learning in the Networked World: The Cyberlearning Opportunity and Challenge*, report of the NSF Task Force on Cyberlearning, June 24, 2008, <http://www.nsf.gov/pubs/2008/nsf08204/nsf08204.pdf>.
2. Mizuko Ito et al., *Connected Learning: An Agenda*

for Research and Design (Irvine, Calif.: Digital Media and Learning Research Hub, 2013), <http://dmlhub.net/publications/connected-learning-agenda-research-and-design> (emphasis in original).

3. For more information on the workshop and for the R&D aspect of the framework, see "New Technology-Based Models for Postsecondary Learning: Conceptual Frameworks and Research Agendas," April 2013, <http://cra.org/resources/research-issues/>.
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