Why IT Matters to Higher Education

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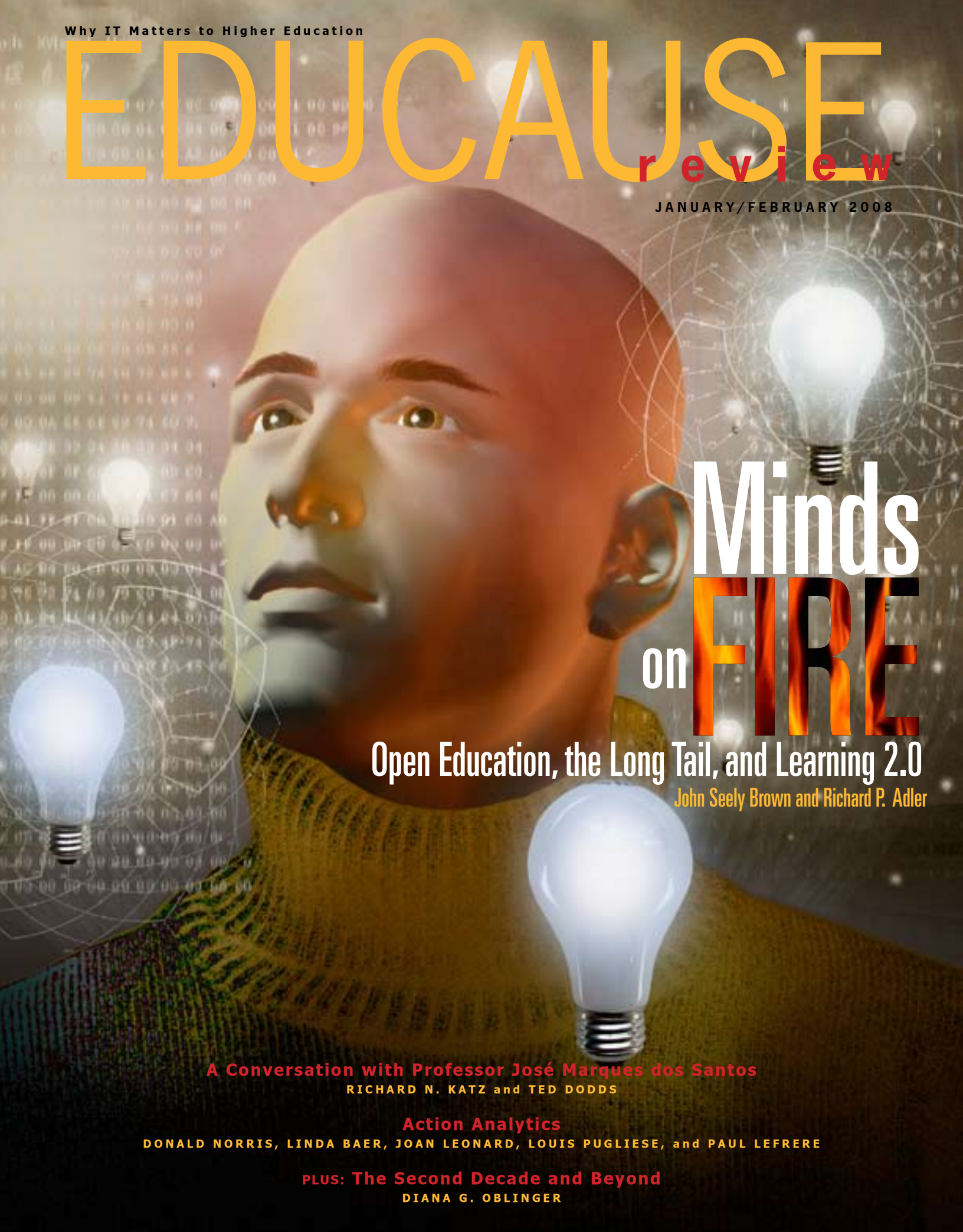

Minds on FIRE

Open Education, the Long Tail, and Learning 2.0

John Seely Brown and Richard P. Adler

A Conversation with Professor José Marques dos Santos
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MINDS ON FIRE

Open Education, the Long Tail, and Learning 2.0

More than one-third of the world's population is under 20. There are over 30 million people today qualified to enter a university who have no place to go. During the next decade, this 30 million will grow to 100 million. To meet this staggering demand, a major university needs to be created each week.

—Sir John Daniel, 1996

By John Seely Brown and Richard P. Adler

The world has become increasingly "flat," as Tom Friedman has shown. Thanks to massive improvements in communications and transportation, virtually any place on earth can be connected to markets anywhere else on earth and can become globally competitive.[1] But at the same time that the world has become flatter, it has also become "spikier": the places that are globally competitive are those that have robust local ecosystems of resources supporting innovation and productiveness.[2] A key part of any such ecosystem is a well-educated workforce with the requisite competitive skills. And in a rapidly changing world, these ecosystems must not only supply this workforce but also provide support for continuous learning and for the ongoing creation of new ideas and skills.

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The most profound impact of the Internet is its ability to support and expand the various aspects of social learning.

If access to higher education is a necessary element in expanding economic prosperity and improving the quality of life, then we need to address the problem of the growing global demand for education, as identified by Sir John Daniel.[3] Compounding this challenge of demand from college-age students is the fact that the world is changing at an ever-faster pace. Few of us today will have a fixed, single career; instead, we are likely to follow a trajectory that encompasses multiple careers. As we move from career to career, much of what we will need to know will not be what we learned in school decades earlier. We are entering a world in which we all will have to acquire new knowledge and skills on an almost continuous basis.

It is unlikely that sufficient resources will be available to build enough new campuses to meet the growing global demand for higher education—at least not the sort of campuses that we have traditionally built for colleges and universities. Nor is it likely that the current methods of teaching and learning will suffice to prepare students for the lives that they will lead in the twenty-first century.

The Brewing Perfect Storm of Opportunity

Fortunately, various initiatives launched over the past few years have created a series of building blocks that could provide the means for transforming the ways in which we provide education and support learning. Much of this activity has been enabled and inspired by the growth and evolution of the Internet, which has created a global "platform" that has vastly expanded access to all sorts of resources, including formal and informal educational materials. The Internet has also fostered a new culture of sharing, one in which content is freely contributed and distributed with few restrictions or costs.

Arguably, the most visible impact of the Internet on education to date has been the Open Educational Resources (OER) movement, which has provided free access to a wide range of courses and other educational materials to anyone who wants to use them. The movement began in 2001 when the William and Flora Hewlett and the Andrew W. Mellon foundations jointly funded MIT's OpenCourseWare (OCW) initiative, which today provides open access to undergraduate- and graduate-level materials and modules from more than 1,700 courses (covering virtually all of MIT's curriculum). MIT's initiative has inspired hundreds of other colleges and universities in the United States and abroad to join the movement and contribute their own open educational resources.[4] The Internet has also been used to provide students with direct access to high-quality (and therefore scarce and expensive) tools like telescopes, scanning electron microscopes, and supercomputer simulation models, allowing students to engage personally in research.

The latest evolution of the Internet, the so-called Web 2.0, has blurred the line between producers and consumers of content and has shifted attention from access to information toward access to other people. New kinds of online resources—such as social networking sites, blogs, wikis, and virtual communities—have allowed people with common interests to meet, share ideas, and collaborate in innovative ways. Indeed, the Web 2.0 is creating a new kind of participatory medium that is ideal for supporting multiple modes of learning.

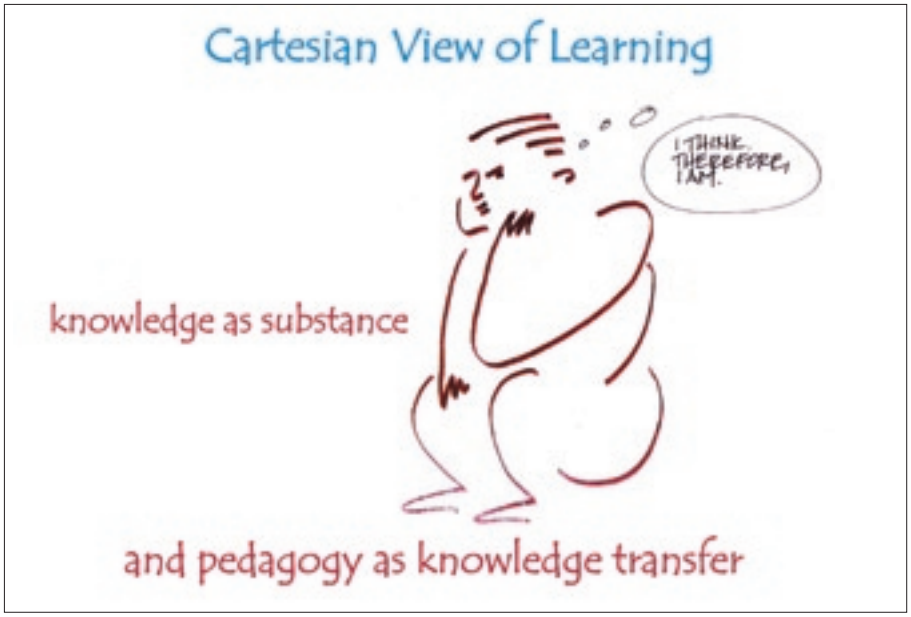
Social Learning

The most profound impact of the Internet, an impact that has yet to be fully realized, is its ability to support and expand the various aspects of social learning. What do we mean by "social learning"? Perhaps the simplest way to explain this concept is to note that social learning is based on the premise that our *understanding* of content is socially constructed through conversations about that content and through grounded interactions, especially with others, around problems or actions. The focus is not so much on *what* we are learning but on *how* we are learning.[5]

Compelling evidence for the importance of social interaction to learning comes from the landmark study by Richard J. Light, of the Harvard Graduate School of Education, of students' college/university experience. Light discovered that one of the strongest determinants of students' success in higher education—more important than the details of their instructors' teaching styles—was their ability to form or participate in small study groups. Students who studied in groups, even only once a week, were more engaged in their studies, were better prepared for class, and learned significantly more than students who worked on their own.[6]

The emphasis on social learning stands in sharp contrast to the traditional Cartesian view of knowledge and learning—a view that has largely dominated the way education has been structured for over one hundred years. The Cartesian perspective assumes that knowledge is a kind of substance and that pedagogy concerns the best way to transfer this substance from teachers to students. By contrast, instead of starting from the Cartesian premise of *"I think, therefore I am,"* and from the assumption that knowledge is something that is transferred to the student via various pedagogical strategies, the social view of learning says, *"We participate, therefore we are."*

This perspective shifts the focus of our attention from the content of a subject to the learning activities and human interactions around which that content is situated. This perspective also helps to explain the effectiveness of study groups. Students in these groups can ask questions to clarify areas of uncertainty or confusion, can improve their grasp of the material by hearing the answers to questions from fellow students, and perhaps most powerfully, can take on the role of teacher to help other group members benefit from their understanding (one of the best ways to learn something is, after all, to teach it to others).



vs.

Learning to Be

There is a second, perhaps even more significant, aspect of social learning. Mastering a field of knowledge involves not only "learning about" the subject matter but also "learning to be" a full participant in the field. This involves acquiring the practices and the norms of established practitioners in that field or acculturating into a community of practice. Historically, apprenticeship programs and supervised graduate research have provided students with opportunities to observe and then to emulate how experts function. Apprentices traditionally begin learning by taking on simple tasks, under the watchful eye of a master, through a process that has been described as "legitimate peripheral participation";[7] they then progress to more demanding tasks as their skills improve. The studio system in architecture represents another example of social learning under the guidance of an established practitioner. In this system, students work together in a common space and peripherally participate in each other's design process; hence they can benefit from their instructors' comments on and critiques of other students' projects and not just from comments on their own work.

A contemporary model that exemplifies the power of this type of social learning is provided by the distributed virtual communities of practice in which people work together voluntarily to develop and maintain open source software. The open source movement has produced software such as the Linux operating system and the Apache web server, which have offered surprisingly robust alternatives to commercial products. These resources are typically made available at no cost to potential users, who are also invited to change or improve the resources as long as they agree to freely share their contributions with others.

Open source communities have developed a well-established path by which newcomers can "learn the ropes" and become trusted members of the community through a process of legitimate peripheral participation. New members typically begin participating in an open source community by working on relatively simple, noncritical development projects such as building or improving software drivers (e.g., print drivers). As they demonstrate their ability to make useful contributions and to work in the distinctive style and sensibilities/taste of that community, they are invited to take on more central projects. Those who become the most proficient may be asked to join the inner circle of people working on the critical kernel code of the system. Today, there are about one million people engaged in developing and refining open source products, and nearly all are improving their skills by participating in and contributing to these networked communities of practice.

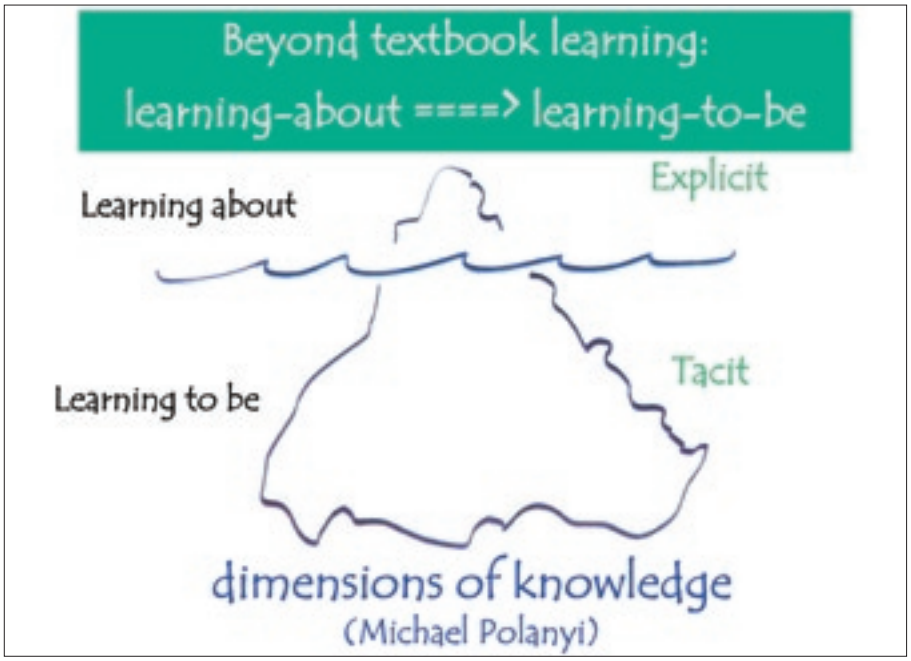
Since the open source movement is based on the development of computer software, participation is effectively limited to people with programming skills. But its principles have been adopted by communities dedicated to the creation of other, more widely accessible types of resources. Perhaps the best known example is Wikipedia, the online "open source" encyclopedia that has challenged the supremacy of commercial encyclopedias. Becoming a trusted contributor to Wikipedia involves a process of legitimate peripheral participation that is similar to the process in open source software communities. Any reader can modify the text of an entry or contribute new entries. But

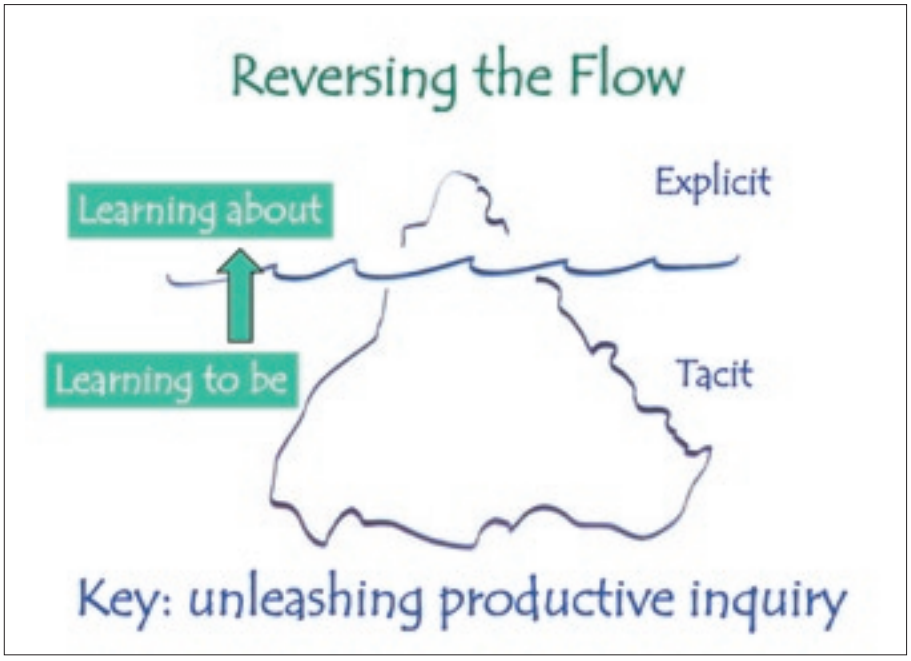
In this open environment, both the content and the process by which it is created are equally visible, thereby enabling a new kind of critical reading.

only more experienced and more trusted individuals are invited to become "administrators" who have access to higher-level editing tools.[8]

The openness of Wikipedia is instructive in another way: by clicking on tabs that appear on every page, a user can easily review the history of any article as well as contributors' ongoing discussion of and sometimes fierce debates around its content, which offer useful insights into the practices and standards of the community that is responsible for creating that entry in Wikipedia. (In some cases, Wikipedia articles start with initial contributions by passionate amateurs, followed by contributions from professional scholars/researchers who weigh in on the "final" versions. Here is where the contested part of the material becomes most usefully evident.) In this open environment, both the content and the process by which it is created are equally visible, thereby enabling a new kind of critical reading—almost a new form of literacy—that invites the reader to join in the consideration of what information is reliable and/or important.

In a traditional Cartesian educational system, students may spend years learning about a subject; only after amassing sufficient (explicit) knowledge are they expected to start acquiring the (tacit) knowledge or practice of how to be an active practitioner/professional in a field.[9] But viewing learning as the process of joining a community of practice reverses this pattern and allows new students to engage in "learning to be" even as they are mastering the content of a field. This encourages the practice of what John Dewey called "productive inquiry"—that is, the process of seeking the knowledge when it is needed in order to carry out a particular situated task.





New Tools for Extending Education: Social Learning Online

Now let's look at some of the ways in which technology has begun to change the game in education by leveraging the potential of social learning—and let's try to identify some of the ways in which technology could bring about even more far-reaching changes that can better serve the needs of twenty-first century students.

A current example of an attempt to harness the power of study groups in a virtual environment is the Terra Incognita project of the University of Southern Queensland (Australia), which has built a classroom in Second Life, the online virtual world that has attracted millions of users.[10] In addition to supporting lecture-style teaching, Terra Incognita includes the capability for small groups of students who want to work together to easily "break off" from the central classroom before rejoining the entire class.

It seems likely that a great deal of informal learning is taking place both on and off campus via the online social networks.

Terra Incognita
Source: http://www.usq.edu.au/newsevents/events/onlinelearning.htm

Instructors can "visit" or send messages to any of the breakout groups and can summon them to rejoin the larger group.

Another interesting experiment in Second Life was the Harvard Law School and Harvard Extension School fall 2006 course called "CyberOne: Law in the Court of Public Opinion." The course was offered at three levels of participation. First, students enrolled in Harvard Law School were able to attend the class in person. Second, non–law school students could enroll in the class through the Harvard Extension School and could attend lectures, participate in discussions, and interact with faculty members during their office hours within Second Life. And at the third level, any participant in Second Life could review the lectures and other course materials online at no cost.

CyberOne Classroom in Second Life
Source: http://blogs.law.harvard.edu/vvvv/files/2006/09/CyberOne_2006-09-21.png

This experiment suggests one way that the social life of Internet-based virtual education can coexist with and extend traditional education.

A very different sort of initiative that is using technology to leverage social learning is Digital StudyHall (DSH), which is designed to improve education for students in schools in rural areas and urban slums in India. The project is described by its developers as "the educational equivalent of Netflix + YouTube + Kazaa."[11] Lectures from model teachers are recorded on video and are then physically distributed via DVD to schools that typically lack well-trained instructors (as well as Internet connections). While the lectures are being played on a monitor (which is often powered by a battery, since many participating schools also lack reliable electricity), a "mediator," who could be a local teacher or simply a bright student, periodically pauses the video and encourages engagement among the students by asking questions or initiating discussions about the material they are watching. The recorded lectures provide the educational content, and the local mediators stimulate the interaction that actively engages the students and increases the likelihood that they will develop a real understanding of the lecture material through focused conversation.[12]

Whereas these examples are using technology to enhance social learning within formal education, it also seems likely that a great deal of informal learning is taking place both on and off campus via the online social networks that have attracted millions of young people. In fact, many students in the United States and in many other parts of the world are already involved with online social networks that include their friends. John King, the associate provost of the University of Michigan, has attempted to bring attention to this phenomenon by asking how many students are being taught each year by his institution. Although about 40,000 students are enrolled in classes on the university's campus in Ann Arbor, King believes that the actual number of

By enabling students to collaborate with working scientists, this movement provides a platform for the "learning to be" aspect of social learning.

students being reached by the school today is closer to 250,000.[13] For the past few years, he points out, incoming students have been bringing along their online social networks, allowing them to stay in touch with their old friends and former classmates through tools like SMS, IM, Facebook, and MySpace. Through these continuing connections, the University of Michigan students can extend the discussions, debates, bull sessions, and study groups that naturally arise on campus to include their broader networks. Even though these extended connections were not developed to serve educational purposes, they amplify the impact that the university is having while also benefiting students on campus.[14] If King is right, it makes sense for colleges and universities to consider how they can leverage these new connections through the variety of social software platforms that are being established for other reasons.

Adding Community to Content: Learning to Be through e-Science and e-Humanities

The e-Science movement is providing students with access to expensive and scarce high-level tools, giving them the opportunity to engage in the kinds of research conducted by professional scientists.[15] By enabling students to collaborate with working scientists, this movement provides a platform for the "learning to be" aspect of social learning. For example, the Faulkes Telescope Project, sponsored by the Las Cumbres Observatory Global Telescope Network, provides students in the United Kingdom with free access to two high-powered robotic telescopes, one in Hawaii and the other in Australia, which the students are able to use remotely to carry out their own scientific investigations (http://faulkes-telescope.com/). The project also operates the Faulkes Telescope Student Academy, which provides training in astronomy and supports collaborative projects between students and expert astronomers. The project's website includes reports of how students, under the guidance of professional astronomers, are using the Faulkes telescopes to make small but meaningful contributions to astronomy.

The Faulkes Telescope Project
Source: http://faulkes-telescope.com/

Hands-On Universe (HOU) is also designed to promote collaborative learning in astronomy (http://www.handsonuniverse.org). Based at the Lawrence Hall of Science, University of California, Berkeley, HOU invites students to request observations from professional observatories and provides them with image-processing software to visualize and analyze their data, encouraging interaction between the students and scientists. According to Kyle Cudworth, the science director at Yerkes Observatory, which is part of the HOU network: "This is not education in which people come in and lecture in a classroom. We're helping students work with real data."[16]

Another, simpler example is the Bugscope project, which gives K–12 students access to a scanning electron microscope located at the Beckman Institute for Advanced Science and Technology at the University of Illinois. Students can send to Illinois any insects (or other small creatures) that they have captured, then log on with their computers to control the microscope in real time and view their specimens (http://bug scope.beckman.uiuc.edu/).

The Internet has also inspired similar innovations in the humanities. The *Decameron* Web, developed by the Italian Studies Department at Brown University, is an impressive example of how the web can not only provide access to scholarly materials but also give students the opportunity to observe and emulate scholars at work (http://www.brown.edu/Departments/Italian_Studies/dweb/dweb.shtml). The site is designed to be the hub for the study of one important literary

The *Decameron* Web
Source: http://www.brown.edu/Departments/Italian_Studies/dweb/dweb.shtml

The emphasis is on building a community of students and scholars as much as on providing access to educational content.

work, the *Decameron*, as well as of the time and culture in which it was produced. In addition to providing the full text of the *Decameron* in Italian and in English translation, the site provides source materials, annotations and commentaries, bibliographies, critical and interpretive essays, and audio and visual materials.

Here too, the emphasis is on building a community of students and scholars as much as on providing access to educational content. The site's developers note: "We fundamentally believe that the new electronic environment and its tools enable us to revive the humanistic spirit of communal and collaboratively 'playful' learning of which the *Decameron* itself is the utmost expression." The site is intended to serve as "an open forum for worldwide discussions on the *Decameron* and related topics." Both scholars and students are invited to submit their own contributions as well as to access the existing resources on the site. The site serves as an apprenticeship platform for students by allowing them to observe how scholars in the field argue with each other and also to publish their own contributions, which can be relatively small—an example of the "legitimate peripheral participation" that is characteristic of open source communities. This allows students to "learn to be," in this instance by participating in the kind of rigorous argumentation that is generated around a particular form of deep scholarship. A community like this, in which students can acculturate into a particular scholarly practice, can be seen as a virtual "spike": a highly specialized site that can serve as a global resource for its field.

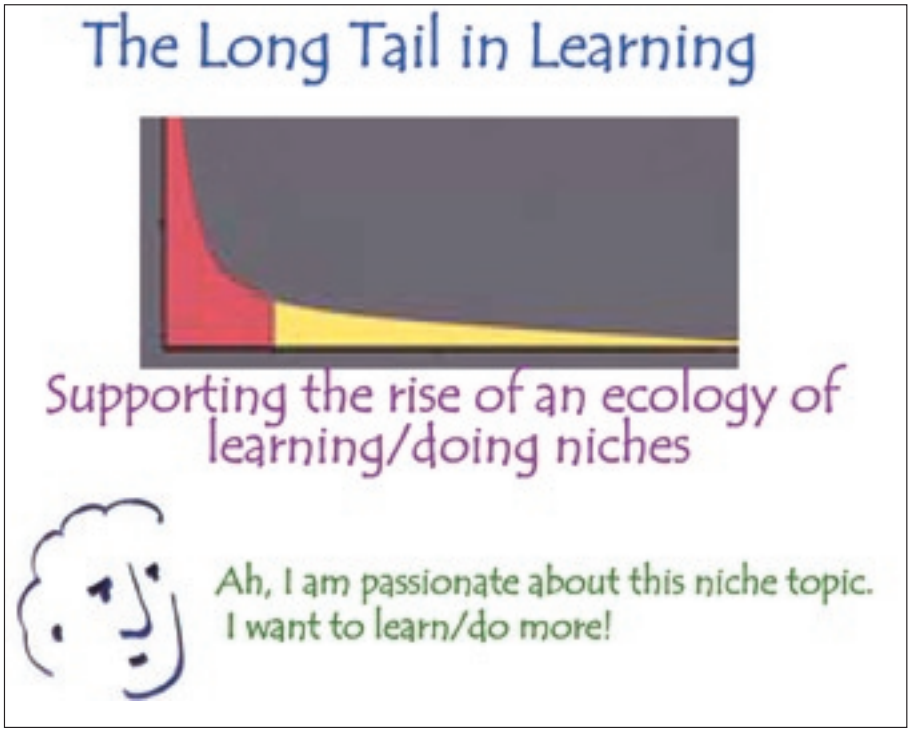
An example of how the power of participation can be harnessed within a single course comes from David Wiley at Utah State University. In the fall of 2004, Wiley taught a graduate seminar, "Understanding Online Interaction." He describes what happened when his students were required to share their coursework publicly:

> Because my goal as a teacher is to bring my students into full legitimate participation in the community of instructional technologists as quickly as possible, all student writing was done on public blogs. The writing students did in the first few weeks was interesting but average. In the fourth week, however, I posted a list of links to all the student blogs and mentioned the list on my own blog. I also encouraged the students to start reading one another's writing. The difference in the writing that next week was startling. Each student wrote significantly more than they had previously. Each piece was more thoughtful. Students commented on each other's writing and interlinked their pieces to show related or contradicting thoughts. Then one of the student assignments was commented on and linked to from a very prominent blogger. Many people read the student blogs and subscribed to some of them. When these outside comments showed up, indicating that the students really were plugging into the international community's discourse, the quality of the writing improved again. The power of peer review had been brought to bear on the assignments.[17]

The Long Tail in Learning

Chris Anderson, the editor of *Wired*, has shown that Internet-based e-commerce differs from commerce in the physical world.[18] In the world of physical retailing, and particularly in areas of selling goods like books, music, and movies, sales are usually dominated by best-sellers. Typically, 20 percent of titles generate 80 percent of all sales, which means that most revenue comes from the "fat" part of the tail and that most of the costs of operation come from maintaining the inventory in the "long" part of the tail.

But Anderson notes that e-commerce sites such as Amazon.com, Netflix, and Rhapsody don't follow this pattern. They are able to maintain inventories of products—books, movies, and music—that are many times greater than can be offered by any conventional store. The result is an economic equation very different from what has prevailed in the physical world: these online stores still have "best-sellers," but the bulk of their sales comes from their vast catalogs of less-popular titles, which collectively sell more than the most popular items



These communities are harbingers of the emergence of a new form of technology-enhanced learning—Learning 2.0.

(or as Anderson sums up the concept by quoting an Amazon.com employee: "We sold more books today that didn't sell at all yesterday than we sold today of all the books that did sell yesterday."[19] From the customers' standpoint, online enterprises offering unprecedented choice are able to cater much more efficiently to individual tastes and interests than any brick-and-mortar store. (Amazon.com and Netflix are able to gain economies by operating a few large, highly efficient fulfillment centers where their inventories of books or movies are stored; in the case of digital music services like Rhapsody, their inventories are entirely virtual, stored as bits on servers.)

As more of learning becomes Internet-based, a similar pattern seems to be occurring. Whereas traditional schools offer a finite number of courses of study, the "catalog" of subjects that can be learned online is almost unlimited. There are already several thousand sets of course materials and modules online, and more are being added regularly. Furthermore, for any topic that a student is passionate about, there is likely to be an online niche community of practice of others who share that passion.

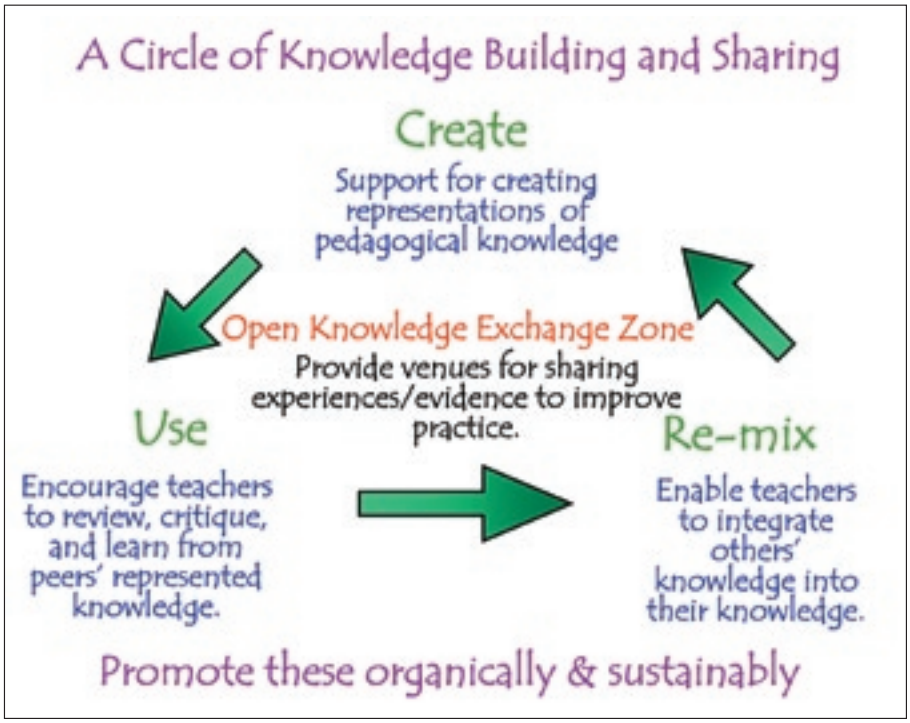
The Faulkes Telescope Project and the *Decameron* Web are just two of scores of research and scholarly portals that provide access to both educational resources and a community of experts in a given domain. The web offers innumerable opportunities for students to find and join niche communities where they can benefit from the opportunities for distributed cognitive apprenticeship. Finding and joining a community that ignites a student's passion can set the stage for the student to acquire both deep knowledge about a subject ("learning about") and the ability to participate in the practice of a field through productive inquiry and peer-based learning ("learning to be"). These communities are harbingers of the emergence of a new form of technology-enhanced learning—Learning 2.0—which goes beyond providing free access to traditional course materials and educational tools and creates a participatory architecture for supporting communities of learners.

Closing the Loop

There are thousands of colleges and universities worldwide, as well as many other institutions of learning, including training centers and technical schools. In addition, there are tens of thousands of institutions that support "informal" learning: libraries, museums, science centers, archives. All of these institutions are practicums—places where knowledge is created and stored and transmitted. But are they reflective practicums? Are they evaluating what they do and engaging in anything resembling cycles of continuous improvement? Are their reflections being systematically captured and shared?

We need to construct shared, distributed, reflective practicums in which experiences are collected, vetted, clustered, commented on, and tried out in new contexts. One might call this "learning about learning," a bootstrapping operation in which educators, along with students, are learning among and between themselves. This can become a living or dynamic infrastructure—itself a reflective practicum.

An example of such a practicum is the online Teaching and Learning Commons (http://commons.carnegiefoundation.org/) launched earlier this year by the Carnegie Foundation for the Advancement of Teaching. The Commons is essentially an open version of the Foundation's Gallery of Teaching and Learning (http://gallery.carnegiefoundation.org/), which has been operating for the past nine years. The Gallery provides an online showcase for case studies of successful teaching and learning projects that have been supported by the Foundation, along with a set of web-based tools (the KEEP Toolkit) for creating these case studies (http://www.cfkeep.org). The Commons is an open forum where instructors at all levels (and from around the world) can post their own examples and can participate in an ongoing conversation about effective teaching practices, as a means of supporting a process of "creating/using/re-mixing (or creating/sharing/using)."[20]



The demand-pull approach is based on providing students with access to rich (sometimes virtual) learning communities built around a practice.

From the Web 2.0 to Learning 2.0

The original World Wide Web—the "Web 1.0" that emerged in the mid-1990s—vastly expanded access to information. The Open Educational Resources movement is an example of the impact that the Web 1.0 has had on education. But the Web 2.0, which has emerged in just the past few years, is sparking an even more far-reaching revolution. Tools such as blogs, wikis, social networks, tagging systems, mashups, and content-sharing sites are examples of a new user-centric information infrastructure that emphasizes participation (e.g., creating, re-mixing) over presentation, that encourages focused conversation and short briefs (often written in a less technical, public vernacular) rather than traditional publication, and that facilitates innovative explorations, experimentations, and purposeful tinkerings that often form the basis of a situated understanding emerging from action, not passivity.

In the twentieth century, the dominant approach to education focused on helping students to build stocks of knowledge and cognitive skills that could be deployed later in appropriate situations. This approach to education worked well in a relatively stable, slowly changing world in which careers typically lasted a lifetime. But the twenty-first century is quite different. The world is evolving at an increasing pace. When jobs change, as they are likely to do, we can no longer expect to send someone back to school to be retrained. By the time that happens, the domain of inquiry is likely to have morphed yet again.[21]

We now need a new approach to learning—one characterized by a *demand-pull* rather than the traditional *supply-push* mode of building up an inventory of knowledge in students' heads. Demand-pull learning shifts the focus to enabling participation in flows of action, where the focus is both on "learning to be" through enculturation into a practice as well as on collateral learning.

The demand-pull approach is based on providing students with access to rich (sometimes virtual) learning communities built around a practice. It is passion-based learning, motivated by the student either wanting to become a member of a particular community of practice or just wanting to learn about, make, or perform something. Often the learning that transpires is informal rather than formally conducted in a structured setting. Learning occurs in part through a form of reflective practicum, but in this case the reflection comes from being embedded in a community of practice that may be supported by both a physical and a virtual presence and by collaboration between newcomers and professional practitioners/scholars.

The demand-pull approach to learning might appear to be extremely resource-intensive. But the Internet is becoming a

vast resource for supporting this style of learning. Its resources include the rapidly growing amount of open courseware, access to powerful instruments and simulation models, and scholarly websites, which already number in the hundreds, as well as thousands of niche communities based around specific areas of interest in virtually every field of endeavor.[22]

The building blocks provided by the OER movement, along with e-Science and e-Humanities and the resources of the Web 2.0, are creating the conditions for the emergence of new kinds of open participatory learning ecosystems[23] that will support active, passion-based learning: Learning 2.0. This new form of learning begins with the knowledge and practices acquired in school but is equally suited for continuous, lifelong learning that extends beyond formal schooling. Indeed, such an environment might encourage students to readily and happily pick up new knowledge and skills as the world shifts beneath them. If they do, we could be taking a major step toward creating a twenty-first-century, global culture of learning to meet Sir John Daniel's challenge and the demands of our constantly changing world. *e*

Notes

1. Thomas L. Friedman, *The World Is Flat: A Brief History of the Twenty-first Century* (New York: Farrar, Straus and Giroux, 2005).
2. See Richard Florida, "The World Is Spiky," *Atlantic Monthly*, October 2005, pp. 48–51, <http://creativeclass.com/rfcgdb/articles/other-2005-The%20World%20is%20Spiky.pdf>.
3. John S. Daniel, *Mega-Universities and Knowledge Media: Technology Strategies for Higher Education* (London: Kogan Page, 1996).
4. For a useful overview of the OER movement by two staff members of the William and Flora Hewlett Foundation, which has been a major supporter of the movement, see Marshall S. Smith and Catherine M. Casserly, "The Promise of Open Educational Resources," *Change: The Magazine of Higher Learning*, vol. 38, no. 5 (September/October 2006), pp. 8–17. For a recent report on the OER movement prepared for Hewlett, see Daniel E. Atkins, John Seely Brown, and Allen L. Hammond, *A Review of the Open Educational Resources (OER) Movement: Achievements, Challenges, and New Opportunities*, February 2007, <http://www.hewlett.org/Programs/Education/OER/OpenContent/Hewlett+OER+Report.htm>.
5. We are interpreting "social" as meaning participating with others and the world. This is a bit nonstandard, since (following Donald Schön) being situated and trying to design or do something, skilled practitioners learn to listen to and interpret the back-talk of the situation. In a sense, one is having a conversation with the material (materiality), and it is "talking back to you." Schön generalizes this to include his key notion of becoming a "reflective practitioner." For a more thorough discussion of this concept, see John Seely Brown, Allan Collins, and Paul Duguid, "Situated Cognition and the Culture of Learning," *Educational Researcher,* vol. 18, no. 1 (January-February 1989), pp. 32–42, <http://www.exploratorium.edu/ifi/resources/museumeducation/situated.html>.
6. Richard J. Light, *Making the Most of College: Students Speak Their Minds* (Cambridge: Harvard University Press, 2001). For a summary of Light's research, see Richard Light, "The College Experience: A Blueprint for Success," <http://athome.harvard.edu/programs/light/index.html>. An earlier, though more focused, contribution to our appreciation of the power of group study was provided by Uri Treisman more than twenty years ago. As a graduate student at UC-Berkeley in the late 1970s, Treisman worked on the poor performance of African-Americans and Latinos in undergraduate calculus classes. He discovered the problem was not these students' lack of motivation or inadequate preparation but rather their approach to studying. In contrast to Asian students, who, Treisman found, naturally formed "academic communities" in which they studied and learned together, African-Americans tended to separate their academic and social lives and studied completely on their own. Treisman developed a program that engaged these students in workshop-style study groups in which they collaborated on solving particularly challenging calculus problems. The program was so successful that it was adopted by many other colleges. See Uri Treisman, "Studying Students Studying Calculus: A Look at the Lives of Minority Mathematics Students in College," *College Mathematics Journal*, vol. 23, no. 5 (November 1992), pp. 362–72, <http://math.sfsu.edu/hsu/workshops/treisman.html>.
7. Jean Lave and Etienne Wenger, *Situated Learning: Legitimate Peripheral Participation* (Cambridge: Cambridge University Press, 1991).
8. Katie Hafner, "Growing Wikipedia Refines Its 'Anyone Can Edit' Policy," *New York Times*, June 17, 2006, <http://www.nytimes.com/2006/06/17/technology/17wiki.html?pagewanted=print>.
9. Michael Polanyi, *The Tacit Dimension* (Garden City, N.Y.: Doubleday, 1966).
10. According to Linden Labs, the developer of Second Life, as of November 6, 2007, more than 10.5 million people had signed up for accounts in the virtual world. In the thirty days prior to that date, just over 980,000 unique individuals had logged in to Second Life, and nearly 500,000 people had logged in during the previous week: <http://secondlife.com/whatis/economy_stats.php>.
11. See <http://dsh.cs.washington.edu/>.
12. In the early 1970s, Stanford University Professor James Gibbons developed a similar technique, which he called Tutored Videotape Instruction (TVI). Like DSH, TVI was based on showing recorded classroom lectures to groups of students, accompanied by a "tutor" whose job was to stop the tape periodically and ask questions. Evaluations of TVI showed that students' learning from TVI was as good as or better than in-classroom learning and that the weakest students academically learned more from participating in TVI instruction than from attending lectures in person. See J. F. Gibbons, W. R. Kincheloe, and S. K. Down, "Tutored Video-tape Instruction: A New Use of Electronics Media in Education," *Science,* vol. 195 (1977), pp. 1136–49.
13. Personal communication from John King to John Seely Brown.
14. For a provocative view of the clash between traditional educational structures (i.e., classroom lectures and blackboards) and the electronically mediated world that young people now live in, see the video created by students in a digital ethnography program at Kansas State University: <http://mediatedcultures.net/ksudigg/?p=122>. The video includes the results of a survey that found that each year, KSU students read an average of 8 books but also read 2,300 web pages and 1,281 Facebook profiles.
15. The National Science Foundation, through its Office of Cyberinfrastructure (http://www.nsf.gov/dir/index.jsp?org=OCI), supports projects that offer students opportunities to engage in advanced research online under the guidance of working scientists.
16. Cudworth quoted at <http://www.handsonuniverse.org/about_hou/history/index.html>.
17. Personal communication from David Wiley, October 15, 2007.
18. Chris Anderson, *The Long Tail: Why the Future of Business Is Selling Less of More* (New York: Hyperion, 2006). A shorter version of Anderson's long tail thesis appeared in *Wired*, issue 12.10, October 2004, <http://www.wired.com/wired/archive/12.10/tail.html>.
19. Josh Peterson, "Definitions: Final Round!" *The Long Tail,* January 9, 2005, <http://longtail.typepad.com/the_long_tail/2005/01/definitions_fin.html>.
20. For more about these web-based resources, see Toru Iiyoshi and Cheryl Richardson (in press), "Promoting Technology-Enabled Knowledge Building and Sharing to Promote Sustainable Open Educational Innovations," in Toru Iiyoshi and M. S. Vijay Kumar, eds., *Opening Up Education: The Collective Advancement of Education through Open Technology, Open Content, and Open Knowledge* (Cambridge: MIT Press, 2008).
21. R. Natarajan, the former director of the Indian Institute of Technology-Madras, recently noted that the "half life of knowledge" in many technical areas is now less than four years. If this is true, then 50 percent of what students learn as undergraduates will be obsolete by the time they graduate and begin seeking employment. See Richard P. Adler, *Minds on Fire: Enhancing India's Knowledge Workforce* (Gurgaon, India: Aspen Institute India, 2007), <http://www.aspeninstitute.org/atf/cf/%7BDEB6F227-659B-4EC8-8F84-8DF23CA704F5%7D/ICT07IndiaMindsonFirefinal.pdf>.
22. Although not discussed here, an additional set of resources consists of the thousands of technical online forums that are emerging around nearly any product or product category, such as digital cameras and computer games, as well as forums emerging around topics related to personal interests such as health or travel.
23. Atkins, Brown, and Hammond, *A Review of the Open Educational Resources (OER) Movement,* use the phrase "open participatory learning infrastructure" (OPLI) instead of "open participatory learning ecosystem," which we use here. We have chosen to use "ecosystem" instead of "infrastructure" to emphasize the emergent interconnections of these resources. To some, the term "infrastructure" suggests a heavyweight, top-down, totally designed artifact. That was not what we had in mind. We envision instead a lightweight, bottom-up, emergent socio-technical structure.