

We welcome your feedback, comments and discussion.
Please post your comments at <http://www.oerdives.org>.

Report to The William and Flora Hewlett Foundation

A Review of the Open Educational Resources (OER) Movement: Achievements, Challenges, and New Opportunities

February 2007

Daniel E. Atkins
John Seely Brown
Allen L. Hammond



THIS WORK IS LICENSED UNDER THE CREATIVE COMMONS ATTRIBUTION 3.0 UNITED STATES
LICENSE. TO VIEW A COPY OF THIS LICENSE, VISIT
<http://creativecommons.org/licenses/by/3.0/us/> OR SEND A LETTER TO CREATIVE COMMONS, 543
HOWARD STREET, 5TH FLOOR, SAN FRANCISCO, CALIFORNIA, 94105, USA

1	INTRODUCTION	1
1.1	Background	1
1.2	Approach and Structure of the Report	5
2	REVIEW OF INVESTMENTS TO DATE	7
2.1	Overall Impact of Investments	7
2.2	Highlights and Examples	8
2.2.1	MIT OCW	8
2.2.2	Connexions Project	10
2.2.3	Utah State University	11
2.2.4	Carnegie Mellon Open Learning Initiative	12
2.2.5	Creative Commons and Internet Archives	13
2.2.6	Comments on Other Projects	15
2.2.7	OpenCourseWare Consortium	21
2.2.8	International Impact	23
2.3	Major Remaining Challenges	24
2.3.1	Introduction	24
2.3.2	Sustainability	24
2.3.3	Curation and Preservation of Access	25
2.3.4	Object Granularity and Format Diversity	26
2.3.5	Intellectual Property Issues	27
2.3.6	Content Quality Assessment and Enhancement	28
2.3.7	Computing and Communication Infrastructure	31
2.3.8	Scale-up and Deepening Impact in Developing Countries	31
3	THE BREWING PERFECT STORM	35
3.1	Introduction	35
3.2	Enablers	38
3.2.1	Open Code and Content	38
3.2.2	Participatory Systems Architecture	39
3.2.3	Improvement in Performance and Access to the Underlying ICT	42
3.2.4	Rich Media, Virtual Environments, and Gaming	43
3.2.5	Emerging Deeper Understanding of Human Learning	45
3.3	Other Complementary Transformative Initiative Areas	46
3.3.1	E-science and Cyberinfrastructure	47
3.3.2	Cyberinfrastructure-Enhanced Humanities	50
3.4	Concluding Remarks	53

4 THE NEXT PHASE: OPEN PARTICIPATORY LEARNING INFRASTRUCTURE (OPLI) INITIATIVE	55
4.1 Introduction	55
4.2 Understanding Infrastructure	55
4.2.1 Fostered, Not Built	56
4.2.2 Dynamics	57
4.2.3 Tensions	57
4.2.4 Design	57
4.2.5 The Long Now of Infrastructure	58
4.3 Learning Enabled by an Open Participatory Learning Infrastructure (OPLI)	60
4.3.1 Peer Learning and Labs on the Wire	62
4.3.2 Exploiting Specialized Resources	63
4.3.3 Content + Context	65
4.4 Some Functional Attributes of an OPLI	66
4.5 Some Thoughts about How	68
4.6 Why Hewlett and Why Now?	69
5 APPENDIX: THE REALITIES OF INFORMATION AND COMMUNICATION TECHNOLOGY IN DEVELOPING REGION AND IMPLICATIONS FOR OER INITIATIVES	71
5.1 The Reality of ICT Infrastructure and Connectivity in Developing Regions	71
5.2 New Technologies and Trends	74
5.3 Venues Ripe for Testing	78

1 Introduction

1.1 Background

In 2002 the Education Program of the Hewlett Foundation introduced a major component into its strategic plan *Using Information Technology to Increase Access to High-Quality Educational Content*. This review¹ begins with this plan as a baseline. Hewlett program officers were motivated to initiate the component after thoroughly examining content for K through 12 and post-secondary levels and finding it “alarmingly disappointing.”

In 1992, when the World Wide Web was launched, open information resources rapidly became freely available, although they were of widely varying quality. With rare exception, the available materials neither promoted enhanced learning nor incorporated the latest technological and pedagogical advances. Educational institutions and publishers, lack of quality assurance for the content, and information overload also impeded the educational impact. During the 1990s, the funding for information technology in education primarily emphasized access to computers and Internet connection and the basic literacy for their use.

The intent of this new Hewlett Foundation program component was to catalyze universal access to and use of high-quality academic content on a global scale. In the spirit of the work of Nobel economist Amartya Sen², the plan is intended to be a strategic international development initiative to expand people’s substantive freedoms through the removal of “unfreedoms”: poverty, limited economic opportunity, inadequate education and access to knowledge, deficient health care, and oppression. The original goal for this program follows:

¹ The review team members are:

- Daniel E. Atkins, Professor of Information, Computer Science and Electrical Engineering at the University of Michigan and Director of the Office of Cyberinfrastructure, U.S. National Science Foundation;
- John Seely Brown, former Chief Scientist of Xerox and Director of its Palo Alto Research Center (PARC); and
- Allen Hammond, Vice President, Special Projects and Innovation at World Resources Institute.

² Amartya Sen, *Development as Freedom*, Knopf: New York, 1999.

To use information technology to help equalize the distribution of high-quality knowledge and educational opportunities for individuals, faculty, and institutions within the United States and throughout the world.

The initial theory and plan of action for the initiative is shown in Figure 1, a precedence of activities culminating in free access to high-quality content to be used by colleges and individuals in the United States and throughout the world to increase human capital. The focus initially was on funding exemplars (living specifications) of high-quality content and building community, collaboration, and a shared knowledge base about the creation, dissemination, and use of open educational resources. In the aggregate the program has addressed the production, access, use, and evaluation of high-quality education content.

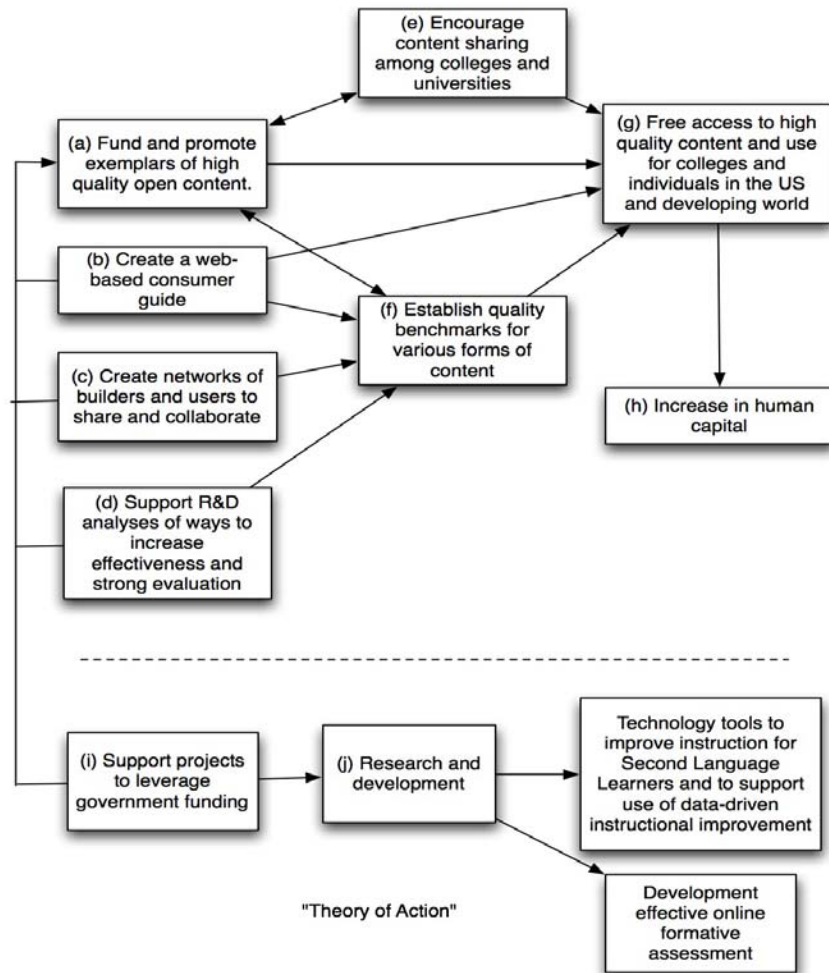


Figure 1—Theory of Action from original strategic plan.

We have reviewed all of the funded projects to varying depths and have reflected upon the extent to which the portfolio of projects cover the original theory of action. As we discuss in Section 2, we find that it has covered quite well the activities above the dotted line. The impact on the developing world is still modest with respect to the enormous need.

The four activities below the dotted line were initiated more recently and are sometimes supported jointly in the Instructional Improvement component of the Education Group and the OER Initiative. For example, Hewlett is now heavily involved in a language learning project call Chengo—Chinese English on the Go. It has committed to completing the project in cooperation with the Ministry of Education in China. Hewlett will also fund a version for Spanish speakers and is attracting interest from many other language groups. The Foundation intends to develop an open language platform and a half dozen or more open, free English teaching programs for other languages. Hewlett reports that a variety of countries are very interested in cooperating. Most of the work it is funding for formative assessment is currently not focusing on open resources but likely eventually will.

We have decided, however, not to dwell on a detailed analysis of the original plan, but to base our review on the triad model featured on the Hewlett OER website and illustrated here in Figure 2. A theme and implicit goal of this model is to build a community so that the emerging OER movement, stimulated by the Hewlett Foundation, will create incentives for a diverse set of institutional stakeholders to enlarge and sustain this new *culture of contribution*.

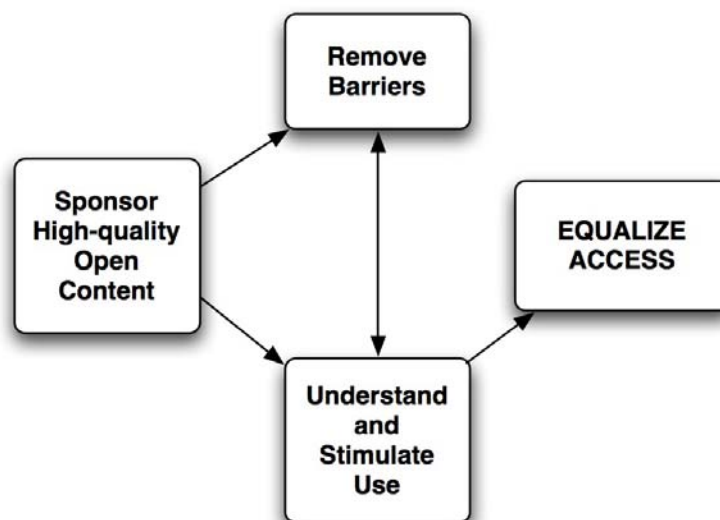


Figure 2—Current Open Educational Resources Logic Model

Figure 3 illustrates the relationship we are assuming between the model in Figure 1 and that in Figure 2.

OER Logic Model	Original Model
Sponsor high-quality open content	a) Fund and promote exemplars of high-quality open content; (f) Establish quality benchmarks for various forms of content.
Remove barriers	(b) Create a web-based consumer guide (barrier of discovery); <i>this list was later augmented to include the barriers of intellectual property, interoperability, multilingualism, culture (mix and remix), and technology infrastructure accessibility.</i>
Understand and stimulate use	(c) Create networks of builders and users to share and collaborate; (d) support R&D analyses of ways to increase effectiveness and make evaluation stronger.

Figure 3—Functional relationship between initial and current model.

The initiative is now often known as the Open Content Initiative or as the Open Educational Resources (OER) Initiative. We will use what we consider the more inclusive term, Open Educational Resources (OER). “Open content” could also include content that is not necessarily educational although in this report we will not make this distinction. The articulation of definitions, goals, and frameworks has, as is appropriate in leading-edge emerging activities, evolved as the Foundation has developed the program with its grantees and others. The description of Open Educational Resources (OER) from the Hewlett website is as follows:

1. **What are Open Educational Resources?**

OER are teaching, learning, and research resources that reside in the public domain or have been released under an intellectual property license that permits their free use or re-purposing by others.³ Open educational resources include full courses, course materials, modules, textbooks, streaming videos, tests, software, and any other tools, materials, or techniques used to support access to knowledge.

³ But not necessarily for commercial use—it depends on which Creative Commons license is used.

2. What are our Goals?

The Hewlett Foundation Open Educational Resources Initiative seeks to use information technology to help equalize access to knowledge and educational opportunities across the world. The initiative targets educators, students, and self-learners worldwide.

3. Why are we funding OER?

At the heart of the movement toward Open Educational Resources is the simple and powerful idea that the world's knowledge is a public good and that technology in general and the World Wide Web in particular provide an extraordinary opportunity for everyone to share, use, and reuse knowledge. OER are the parts of that knowledge that comprise the fundamental components of education—content and tools for teaching, learning, and research.

4. What Do We Focus On?

We support the development and dissemination of high-quality content; innovative approaches to remove barriers to the creation; use, re-use and sharing of high-quality content; and projects that seek to improve understanding of the demand for openly available content.

We have conducted our review of several of the larger projects, a scan of all of the funded projects through the study of internal Hewlett documentation, external releases, and the websites of most projects. We participated in site visits to MIT OCW,⁴ Rice Connexions Project,⁵ and Utah State⁶ and participated in several of the emerging OCW Consortium⁷ meetings. We have had ad hoc discussions with several of the leaders of current major grants and extensive discussions with each other as well as with Marshall Smith and Catherine Casserly.

1.2 Approach and Structure of the Report

In Section 2 we will review the portfolio of OER grants to date in the context of the overall Technology/Open Educational Resources Logic Model and the description and goals above. From 2002 to the present the Hewlett Foundation has invested about \$68 million in the OER program. We will comment on the distribution of grants across the various activities of the model, focus on important successes, and note areas that need more attention. We will particularly emphasize the unique contributions that Hewlett investments have made in both launching and moving forward the OER movement. We believe

⁴ <http://ocw.mit.edu/index.html>

⁵ <http://cnx.org/>

⁶ <http://ocw.usu.edu/>

⁷ <http://ocwconsortium.org/>

it has achieved a nascent movement status. A *field* of OER activity—a new culture of contribution—is emerging. The initiative has invested internationally in a way that builds capacity for *engagement* based on mutual benefit between people and institutions between and within developed and developing regions. In the next section we look in more detail at the portfolio of grants.

In Section 3 we describe threads of activity that we believe complement the OER activities supported by Hewlett and that provide Hewlett and other funders the opportunity for convergence into the next phase of investment and impact. The OER initiative has nurtured a culture of sharing, not only within individuals, but also within major institutions of higher education. It has helped shift faculty perspectives from *this courseware is mine* to *this courseware is for (open) mining*. The next phase is to nurture a culture of learning in which both intellectual capital (content) and human capital (talent) spiral upward, together. The conditions now exist, we believe, to consolidate understanding, technology, and incentive from multiple threads of activity into an open participatory learning infrastructure (OPLI).

A socio-technical initiative to form an open participatory learning infrastructure is critical to this culture of learning. By open participatory learning infrastructure we mean the institutional practices, technical infrastructure, and social norms that allow a smooth operation of globally distributed, high-quality open learning. We include the word “participatory” to emphasize that the focus is not just on information access, but on the role of technology in supporting the social nature of learning. An OPLI can leverage diversity of use, radical repurposing of content, and critical reflection.

This perspective is consistent with *collaboratories* in science and humanities communities and the *social software* and the *Web 2.0* movement more generally. Such an infrastructure supports diverse ecosystems of people and learning resources that could have profound implications for preparing people for a rapidly evolving knowledge-based world, one demanding creativity, innovation, and entrepreneurialism from us all. The OPLI should provide participatory architectures for emerging visions and concepts such as the meta-university, the university in and of the world, “learning to be” sooner rather than later, and global-scale massification of higher education.⁸ It also extends across level and age: K–12, higher education, and lifelong learning.

Finally, in Section 4 we elaborate on some of the opportunity resulting from the convergence of the threads of activity described in the previous section and we suggest a next phase for Hewlett educational investments. We also make specific suggestions about how Hewlett might approach defining, awarding, and managing the initiative.

⁸ Charles M. Vest, “Open Content and the Emerging Global Meta-University,” *EDUCAUSE Review*, May/June 2006, <http://www.educause.edu/apps/er/erm06/erm0630.asp?bhcp=1>

2 Review of Investments to Date

2.1 Overall Impact of Investments

In this section we present a qualitative retrospective evaluation of the Hewlett OER program. The evaluation is based on a survey of 134 grants and their websites made in 2002 to 2006, in-depth reviews of some of the largest and most significant grants, ad hoc conversations with grantees, and extensive discussions with Marshall Smith and Catherine Casserly.

We began with a review of Component 2 of the Strategic Plan for the Education Program, which is dated October 2002 and titled Using Information Technology to Increase Access to High-Quality Educational Content. This plan, which is summarized in the Theory of Action drawing in Figure 1, has served well as a framework for the portfolio of OER investments from 2002 to 2006. In reviewing the grant portfolio with respect to the original Theory of Action, we decided to adopt the later simplified model shown in Figure 2. We have done a first-order classification of the 134 grants with respect to the three goal components in service of equity of access: providing high-quality open content, removing barriers, and understanding and stimulating use. We associated *reducing barriers* with technology issues and *understanding and stimulating use* with R&D, feasibility studies, plus awareness creation. In the final analysis, however, we could not make a clear distinction between these later two and thus merged them.

Under these assumptions we estimate that of the total of \$68 million in grants, \$43 million has gone to the creation and dissemination of open content and \$25 million into reducing barriers, understanding, and/or stimulating use. Of the total, about \$12 million has gone to non-U.S. institutions primarily in Europe, Africa, and China for capacity building, translation, and/or stimulation of established institutions such as the Open University in the United Kingdom and Netherlands so they will be more aggressive in providing open content. About half of the \$12 million has gone to enhance the ability of developing countries to take advantage of the open content and contribute to it.

The goal of high quality has been achieved largely by supporting branded content from well-established, high-reputation institutions. This is a reasonable starting point, but as we will discuss in later sections, in the future Hewlett needs to find additional mechanisms for vetting and enhancing educational objects in social settings, ways to close loops and converge to higher quality and more useful materials.

Overall we are impressed with the systematic balance of the OER portfolio and the effort that has gone into creating a microcosm of a global-scale activity. We note here a point we will reinforce later: private foundations like Hewlett have

much more flexibility (and thus we would argue, the responsibility) for investment both inside and outside the United States than do, for example, government institutions like the National Science Foundation. Hewlett also has more flexibility and freedom to take risks in a global grantee community. What it has done with OER would be impossible for NSF. We are very impressed with how well Hewlett has engaged in strategic but risky projects and nurtured them when necessary. We think this is why it has accomplished so much in such a short time, especially with respect to the global nature of the investments.

Although we surmise that some of the smaller grants did not meet expectations and that some opportunities were missed, the yield on the overall investment portfolio is spectacular. Hewlett has more than met the goals of the original strategic plan and in fact has been a major catalyst (arguably **the** major catalyst) in advancing OER into a growing movement. Most remarkable is the extent to which OER has moved *education institutions*, not just individuals and small groups, to embrace a new culture of IT-enabled contribution and sharing. The impact of the Hewlett OER investments now go well beyond the institutions it has directly funded.

For example a quick browse of the website of the OpenCourseWare Consortium⁹ reveals a collaboration of more than 120 higher education institutions and associated organizations from around the world “creating a broad and deep body of open educational content using a shared model.”

The mission of the OpenCourseWare Consortium is to advance education and empower people worldwide through open courseware. Only a small fraction of these 120 organizations¹⁰ have received direct funding from Hewlett. And of course the OpenCourseWare Consortium does not include all the recently established OER type activities, for example, the Curriki¹¹ activities initiated by Scott McNealy, CEO of Sun Microsystems. Hewlett has played a true leadership role in building both a field and a community.

2.2 Highlights and Examples

2.2.1 MIT OCW

The flagship of the OER investments is the MIT OpenCourseWare Project. This world-changing project emerged from MIT faculty and administrators who

⁹ <http://www.ocwconsortium.org>

¹⁰ We have not looked carefully at the density of participation in OCW at all of these institutions. We understand, however, that to belong to the OCW, Consortium institutions must offer at least ten open courses and confirm institutional, rather than just individual faculty commitment.

¹¹ <http://www.curriki.org/>

asked themselves the following question: “How is the Internet going to be used in education and what is our university going to do about it?”

The answer from the MIT faculty was this: “Use it to provide free access to the primary materials for virtually all our courses. We are going to make our educational material available to students, faculty, and other learners, anywhere in the world, at any time, for free.”

Atkins chaired an in-depth review of the OCW project in the fall of 2005 and Brown serves on the OCW advisory committee. The OCW project at MIT has created a very successful, compelling, living existence proof of the power of high-quality open educational resources. It is a pioneering project that has now become a catalyst for a nascent open courseware movement in service of both teachers and learners. Borrowing from the review by Atkins, et. al. we summarize impact as follows:

- Creation and continuing execution of a well-tuned process to obtain and convert most of the MIT course material to consistent .pdf formats, and to make this material freely available, to the extent possible without copyright violation, to the world.
- Commitment by a growing number of U.S. higher education institutions (community colleges through research universities) to an OCW Consortium offering open access to at least some of their courseware. There is a growing sense that there is room in the world for more than MIT courses and a growing diversity in both the topic and level of available open courseware.
- Commitments by non-U.S. higher education institutions to build new curriculum or transform current curriculum using open courseware resources.
- Investment by non-U.S. institutions to translate courseware from the United States into local languages and to make the translations also openly available.
- Early commitments by non-U.S. institutions to add to the store of open courseware in their local language.
- Encouraging signs of positive impact of OCW on education in developing countries.
- Growing evidence of positive impact on the students and faculty at the OCW supplying institution.
- Development of tools intended to facilitate the production (including IP scrubbing) of open courseware, e.g. eduCommons, as well community authoring and reuse of open educational objects, e.g. Connexions.

- Emergence of searching tools for open educational resources, for example, a subset of the Internet Archive.
- Increasing attention to the relationship between open courseware production and the development of open source course management systems (e.g. the Sakai Project).
- The growing appreciation of the Creative Commons project, including most germane to OCW, the *attribution* and *share alike* licenses
- Strategic visions about the future of higher education and concepts of global meta universities from academic thought leaders such as Charles M. Vest (President Emeritus of MIT) and James J. Duderstadt (President Emeritus of the University of Michigan) fueled in part by the OCW movement.

MIT is now reporting close to 16 million visits since October 2003; these visits are split about evenly between first-time and repeat visits. The site now includes some material for most every course taught at MIT. Although the mix of material varies by course, the overall mix now includes the following: syllabus, course calendar, lecture notes, assignments, exams, problem and solution sets, labs and projects, hyper-textbooks, simulations, tools and tutorials, and video lectures. There is extensive detail on the use and impact on the MIT OpenCourseWare website.

2.2.2 Connexions Project

The MIT OpenCourseWare Project is noteworthy in its scale, completeness, quality, and positive influence on others. It is, however, basically a digital publishing model of high-quality, pre-credentialed, static material. The Connexions Project complements the MIT project in that it provides not only a rapidly growing collection of free scholarly material but also a set of free software tools to help authors publish and collaborate; instructors build rapidly and share custom courses; and learners explore the links among concepts, courses, and disciplines. It focuses on building and supporting communities of digital object consumers and producers who credential material.

Connexions is an environment for collaboratively developing, freely sharing, and rapidly publishing scholarly content on the Web. Although Connexions began with a focus on digital signal processing, its Content Commons now contains educational materials for a wide audience, from children to college students to professionals, organized in small modules across growing topic areas that are easily connected to larger courses. All content is free to use and reuse under the Creative Commons attribution license.

Connexions feels more like an ecosystem than a library with rich cross links that can compose new learning objects from old ones. It is thus a start toward an

infrastructure that enables one to remix and compose new objects from old ones. It has been especially effective in exploring modularity and granularity: What is the right grain size that enables maximal reuse of the material? The project has also started exploring the significance of integrating the tools for design with the material to understand (e.g. the DSP material plus a system design toolkit).

The project leaders now report that Connexions has become internationally focused, interdisciplinary, and grassroots organized. More than one million people from 194 countries are tapping into the 3,755 modules and 197 courses developed by a worldwide community of authors in fields ranging from computer science to music and from mathematics to biodiversity. In addition to modules written in English, one can find modules written in Chinese, Italian, Japanese, Portuguese, Spanish, and Thai.

2.2.3 Utah State University

Utah State University has been a major grantee in the OER program as a provider of open content¹² and as a free source of open learning support through the Center for Open and Sustainable Learning (COSL).¹³ The Center provides support to others interested in starting OCW at their institutions. It has developed eduCommons, an OCW management system with workflow process that guides users in publishing materials in an openly accessible format. This includes uploading materials into a repository, dealing with copyright, reassembling materials into courses, providing quality assurance, and publishing materials.

We understand that COSL is now moving toward a clearinghouse for inventory and evaluation of OER tools, systems, and best practices other than those it creates. It will focus on open tools that will be especially useful in the developing world where access and bandwidth are limited.

eduCommons is intended to reduce technical barriers and cost for creating MIT-type OCW websites and to enforce a workflow model that supports quality control and scrubbing the content clean of intellectual property (IP) infringements. Initially, at least, it seems to focus on helping institutions move web-based course material to open access with a more homogenous look and feel. The workflow model enforces a set of human roles with varying rights of review, editing, and publishing. This model is intended to provide an institution with the means to assure academic and pedagogical quality, and to assure that no material is used that violates terms and conditions of copyright or licenses. eduCommons is also the production environment from which course material is served to the world.

¹² <http://ocw.usu.edu/>

¹³ <http://cosl.usu.edu/projects>

The philosophy of the COSL team is that all resources emitted by eduCommons should be covered by an “educational” Creative Commons license and that an institution will have people interacting with the workflow model to ensure this is the case. As yet, there are no tools provided to help those responsible know whether included material is copyright free. The Utah State group needs to be cautious about statements they have made along the lines that “everything coming out of eduCommons would be scrubbed IP clean.” That would be the case if only people, using the workflow model, made sure this was the case—the system alone will not do the “scrubbing.”

This philosophy suggests that two different digital course resource systems would emerge within a university: one built entirely of creative commons material, and another built within the IP environment of the institution’s digital library/repository allowing access to copyright material only to authenticated members of community.

The Utah State Open Learning Support¹⁴ (OLS) is a website where individuals can connect to share, discuss, ask, answer, debate, collaborate, teach, and learn. These meetings are consistent with move toward using social software to form communities of learners around open content, but this site has not yet really taken off as has the total access to OCW materials.

Utah State’s direct provision of open courseware provides an example of why there is room for many in this activity—why elite MIT having all of its courses online does not corner the market. Network-based OER can provide access to “long tail” distributions of very specialized and diverse content. For example, Utah State has a very strong program in applied water management and irrigation and open courses in this area have been eagerly adopted in developing countries, especially in arid regions. Indeed in the learning ecosystem models we will discuss later, one would like to see the truly distinctive specializations in any given school be brought forward. Eventually it might be the specializations that together that form the fabric of a “meta-university.”

2.2.4 Carnegie Mellon Open Learning Initiative

The Carnegie Mellon Open Learning Initiative¹⁵ (OLI) adds a focus to the OER portfolio on instructional design grounded in cognitive theory, formative evaluation for students and faculty, and iterative course improvement based on empirical evidence. OLI courses include a number of innovative online instructional components such as cognitive tutors, virtual laboratories, group experiments, and simulations. We include a summary of the project, largely taken from the project website, because the approach of this project is complementary to the MIT OCW and Rice Connexions Project and

¹⁴ http://mit.ols.usu.edu/index_html

¹⁵ <http://www.cmu.edu/oli/index.html>

fundamental to the future directions we advocate in Section 4.

Cognitive theory and faculty expertise guide the initial development of each course. OLI researchers conduct a variety of studies to examine the effectiveness of various educational innovations. The results not only improve the courses, but also enhance the knowledge about effective practices in online learning.

Students and faculty who use the courses benefit from the evaluation that is built into all courses. Frequent formative evaluation gives students the type of constructive and timely feedback on progress that is available from individual tutoring sessions but often absent from other digital learning environments. Continuous evaluation of class performance gives faculty the information they need to effectively modify or supplement instruction to meet learning objectives.

A primary objective of the project is to build a community that will play an important role in course development and improvement. The courses are developed in a modular fashion to allow faculty at a variety of institutions to either deliver the courses as designed or to modify the content and sequence to fit the needs of their students and/or their curricular and course goals. These courses will be broadly disseminated at no cost to individual students and at low cost to institutions.

The first courses developed through OLI are introductory courses intended to replace large lecture format courses in economics, statistics, causal reasoning, and logic. The courses are highly effective, intellectually challenging sequences of instruction that reflect not just cutting-edge technology but some compelling ideas about pedagogy and content of introductory college-level instruction.

OLI, according to its website, is intended to have a profound impact on higher education by increasing access to education, enhancing the quality of instruction, and providing a model for online courses and course materials that teach more effectively and appeal to students more powerfully than anything in existence today.

2.2.5 Creative Commons and Internet Archives

Creative Commons,¹⁶ with a tagline of *share, reuse, and remix, legally*, is a critical infrastructure service for the OER movement providing free tools that let authors, scientists, artists, and educators easily mark their creative work with the freedoms they want it to carry. They can change the default copyright terms from “All Rights Reserved” to “Some Rights Reserved.”

¹⁶ <http://creativecommons.org/>

Creative Commons is a companion to the OER initiative and was founded in 2001 to help revive the shrinking public domain as copyright durations were repeatedly extended in large part due to the pressures from the media industry. They use private rights to create public goods: creative works set free for certain uses. Like the free software and open-source movements, their ends are cooperative and community-minded, but the means are voluntary and libertarian.

Creative Commons has developed a Web application that helps people dedicate their creative works to the public domain or retain their copyright while licensing them as free for certain uses, on certain conditions. Unlike the GNU General Public License,¹⁷ Creative Commons licenses are not designed for software but for other kinds of creative works: websites, scholarship, music, film, photography, literature, courseware, etc. The aim is not only to increase the sum of raw source material online, but also to make access to the material cheaper and easier. To this end, they have also developed metadata that can be used to associate creative works with their public domain or license status in a machine-readable way. A goal is to enable people to use search and other online applications to find, for example, photographs that are free provided the original photographer is credited, or songs that may be copied, distributed, or sampled with no restrictions whatsoever.

As of June 2006 about 140 million web pages link to a CC license, according to Google, and there are over 25 million CC-licensed photographs on Flickr as of December 2006. Creative Commons licenses are the basis for numerous open resource repositories such as Science Commons and Public Library of Science. The MIT OCW has adopted the Creative Commons Attribution, Noncommercial, ShareAlike (By-NC-SA) license. All of this is fundamental infrastructure for the OER movement and thus Hewlett has quite wisely lent sustaining financial support to Creative Commons.

Similarly Hewlett has helped support the Internet Archives.¹⁸ It is another critical component of infrastructure for the OER movement, as it offers researchers, historians, and scholars permanent access to historical collections that exist in digital format. Fortunately, such institutions are growing in number and sophistication, but Brewster Kahle's Internet Archives has been a pioneer in this area. The Internet Archives is now creating a digital library of Internet sites and other cultural artifacts in digital form. It provides free access to researchers, historians, scholars, and the general public.

¹⁷ GNU is the name of an operating system project circa 1984 headed by Richard Stallman who pioneered the free software movement.

¹⁸ <http://www.archive.org/index.php>

2.2.6 Comments on Other Projects

It is not within the scope of this report to review in depth all of the projects in the OER portfolio. We will, however, scan the landscape and provide comments on others, clustered in five topical areas, to help illustrate the scope of the portfolio and project areas besides the projects we have highlighted. We will focus on international activities in Section 2.2.7 although we will not exclude international programs from this section. These projects indicate some very good beginnings but are still largely an ad hoc collection. This is appropriate for the phase of activities to date, but a more strategic and related set of projects need to evolve.

1. **Incubation of High-Quality Specialized Open Resources**—Here we summarize the projects other than the few we highlighted earlier for creating and sharing high-quality open educational resources. The projects range from very specialized open knowledge sites and data sets to comprehensive collections and curricula.
 - a. Coastline Community College is developing Chengo,¹⁹ an online Chinese and English language learning system and to adapt for Spanish learners as well.
 - b. Cold Spring Harbor Laboratory is developing, evaluating, and disseminating Genes to Cognition (G2C) Online,²⁰ an Internet site modeled on principles of neural networking, which examines current research to discover the molecular and cellular basis of human thinking.
 - c. Harvard University continues to develop the Open Collections Program,²¹ making Harvard’s library treasures freely available on the web.
 - d. Foothill–De Anza Community College District is developing SOFIA²² (Sharing of Free Intellectual Assets)—a collaboration of California community colleges to provide quality online.
 - e. Johns Hopkins University is developing the Johns Hopkins Bloomberg School of Public Health OpenCourseWare.²³
 - f. Monterey Institute for Technology and Education is developing the National Repository of Online Courses,²⁴ a library of high-

¹⁹ <http://www.elanguage.cn/>

²⁰ <http://www.genes2cognition.org/>

²¹ <http://ocp.hul.harvard.edu/>

²² <http://sofia.fhda.edu/>

²³ <http://ocw.jhsph.edu/>

quality high school, Advanced Placement©, and undergraduate courses that are distributed free to students and teachers and through various licensing fees.

- g. National Science Teachers Association²⁵ is developing open online science learning objects for K–12 science teachers.
- h. Open Universiteit Nederland is working on the OpenER²⁶ project to introduce OER to Dutch higher education by focusing on high-quality, independent self-study learning materials in an open resource format.
- i. Open University (UK)²⁷ is making selections of its higher education learning resources freely available on the Internet, providing users with tools to help them manage their learning, and developing supported collaborative learning communities.
- j. Stanford University²⁸ is creating and testing open web-based resources for supporting the teaching and learning of U.S. history.
- k. Stanford University²⁹ is developing a strategy to reach financial sustainability for the online, open Stanford Encyclopedia of Philosophy.
- l. Tufts University continues to publish Tufts OpenCourseWare,³⁰ which focuses on dental and veterinary medicine as well as international affairs.
- m. University of California, Berkeley³¹ is creating an open online general chemistry course.
- n. University of California, Irvine³² is developing open courses and support materials to prepare California teachers for a teaching credential in mathematics.

²⁴ <http://www.montereyinstitute.org/nroc/>

²⁵ <http://learningcenter.nsta.org/>

²⁶ <http://www.ou.nl/ecache/def/36.html>

²⁷ <http://www.open.ac.uk/>

²⁸ <http://www.historymatters.gmu.edu/>

²⁹ <http://plato.stanford.edu/>

³⁰ <http://ocw.tufts.edu/>

³¹ <http://chem1a.berkeley.edu/>

³² <http://unex.uci.edu/>

- o. Nobel Laureate Carl Wieman at the University of Colorado³³ is developing interactive simulations and guided activities for teaching chemistry and physics.
- p. The Notre Dame OpenCourseWare³⁴ project at the University of Notre Dame is developing thirty courses in ethics, philosophy, theology, anthropology, and peace and international studies.
- q. University of Washington is preparing two educational computer simulations, LEGSIM³⁵ and Election Day,³⁶ on the legislative process and of elections, for widespread, open use.
- r. WGBH is developing new science teaching resources in WGBH's Teachers' Domain³⁷ and making them openly available online.
- s. Yale University is creating digitized audio-visual content for undergraduate liberal arts instruction. It will be offered freely through the Internet and managed by its Center for Media Initiatives.³⁸
- t. Yale University is making published scientific research on the environment available through Online Access to Research in the Environment (OARE³⁹) open to public and nongovernmental organizations in developing countries.
- u. Alexandra Archive Institute⁴⁰ is compiling archaeological data.

2. Capacity Building in Developing Countries for Effective Use of OER

- a. Academy for Educational Development for the Global Learning Portal⁴¹ project is designing a website supporting educators in developing countries.

³³ <http://www.colorado.edu/physics/phet>

³⁴ <http://ocw.nd.edu/>

³⁵ <http://www.legsim.org/>

³⁶ <http://www.election-day.info/>

³⁷ <http://www.teachersdomain.org/>

³⁸ <http://cmi2.yale.edu/cgi-bin/cmi2/news.cgi?group=&year=2006&story=1>

³⁹ <http://www.oaresciences.org/en>

⁴⁰ <http://www.alexandriaarchive.org/>

⁴¹ <http://www.glp.net>

- b. African Virtual University is creating a comprehensive Open Educational Resources Architecture to ensure the efficient and effective application of the open content movement in African higher education and training institutions and is initiating related capacity-building activities.
- c. African Virtual University⁴² is creating the Teacher Education in Sub-Saharan African project.
- d. Development Gateway Foundation⁴³ is developing a topic page on Open Educational Resources (OER) for the web-based portal.
- e. Fantasy Foundation of Culture and Arts is supporting the Opensource Opencourseware Prototype Systems (OOPS⁴⁴) in Taiwan.
- f. IET Foundation is selecting, translating, adopting, and using OpenCourseWare materials from MIT and other OCW institutions by Chinese Universities. It is also translating original course materials from Chinese Universities for use globally to enhance education, through Chinese Open Resources for Education (CORE⁴⁵).
- g. Meraka Institute⁴⁶ is developing a collection of papers describing use of OER in tertiary education, in primary and secondary schools, and within communities in South Africa.
- h. United Nations Educational Scientific and Cultural Organization International Institute for Educational Planning⁴⁷ are creating an international community of practice on Open Educational Resources.
- i. University of Iowa for WiderNet⁴⁸ is delivering and sharing open educational resources in Africa.
- j. University of Mauritius⁴⁹ is holding the ICOOL Conference (International Conference on Open and Online Learning) in South Africa.

⁴² <http://www.open.ac.uk/tessa/>

⁴³ <http://topics.developmentgateway.org/openeducation>

⁴⁴ <http://oops.editme.com>

⁴⁵ <http://www.core.org.cn/en/index.htm>

⁴⁶ <http://www.meraka.org.za/>

⁴⁷ <http://www.unesco.org/iiep/virtualuniversity/forums.php>

⁴⁸ <http://www.widernet.org/>

- 3. Toward Building a Relevant Research Community**—The initial phase has quite properly focused on building and assessing pilot projects. Here, however, are some OER projects that are primarily focusing on related R&D – on OER as an object of study. In future activities there is a need to nurture a more coherent field of study around and about OER. There are research components included in most of the large projects together with a few more generic academic research projects such as the following:
- a. Boston College is establishing a new online *Journal of Technology, Learning and Assessment*.⁵⁰
 - b. Brandeis University is developing SpellBee⁵¹, a peer-to-peer technology-based community project for young learners.
 - c. Forum for the Future of Higher Education⁵² is developing and implementing a forum on human cognition and new technologies.
 - d. Organisation for Economic Cooperation and Development⁵³ is conducting an international study of demand and supply side issues related to Open Educational Resources and creating E-learning case studies in post-secondary education and training.
 - e. Stanford University⁵⁴ is organizing a working group to plan for large-scale digitization of Arabic-language books.
 - f. University of California, Berkeley’s Center for Studies in Higher Education⁵⁵ is studying the use of web-based collections of open academic content.
- 4. Building Awareness, Voice, and Understanding**—Some of the projects have given voice to the OER movement, building understanding, capacity, and action in various stakeholder communities, including policy formulators. These include:
- a. A Columbia University⁵⁶ project is teaching educators, technologists, video producers, and other stakeholders about uses of video and open content.

⁴⁹ <http://vcampus.uom.ac.mu/vcilt/index.htm>

⁵⁰ <http://escholarship.bc.edu/jtla/>

⁵¹ <http://spellbee.org/>

⁵² <http://www.educause.edu/forum/>

⁵³ <http://www.oecd.org/edu/oer>

⁵⁴ <https://www.bibalex.org/digiarab/>

⁵⁵ <http://cshe.berkeley.edu/research/digitalresourcestudy/index.htm>

- b. Commonwealth of Learning⁵⁷ is supporting Open Educational Resources activities to infuse the principles of Open Educational Resources into the Commonwealth of Learning's wide array of activities.
 - c. European Association of Distance Teaching Universities⁵⁸ is in the first stage of an effort to explore using free web-based courses to stimulate learning among all people.
 - d. Institute for the Study of Knowledge Management in Education⁵⁹ is building a website to increase awareness and understanding about open educational resources (OER) and to provide support for needed OER field-building activities.
 - e. New America Foundation⁶⁰ is accelerating the constructive dialogue between commercial and noncommercial stakeholders active in the digitization and publication, broadly defined, of educational and cultural heritage materials.
 - f. One Economy⁶¹ is improving content on an online education website and supporting a youth technology program benefiting the residents of affordable housing developments in San Francisco and San Jose.
5. **General software and middleware services infrastructure for creating, federating, and finding OER resources**—Besides the software developed within the context of specific OCW projects, there have been some activities related to creating generic software and services and/or linking with existing open source middleware projects. The Open University UK under LabSpace⁶² and the Rice Connexions Project have also created open tools.
- a. Foothill–De Anza Community College District (with the University of Michigan) is implementing the next generation of the Easy to Use Distance Education System⁶³ (ETUDES-NG) open source software across California community colleges, and is contributing to the development and enhancement of tools to support online learning

⁵⁶ <http://ccnmtl.columbia.edu/web/>

⁵⁷ <http://www.col.org/colweb/site>

⁵⁸ <http://www.eadtu.nl/>

⁵⁹ <http://www.oercommons.org/>

⁶⁰ <http://www.conference.archival.tv/index.php?title=Program>

⁶¹ <http://www.thebeehive.org/>

⁶² <http://labspace.open.ac.uk/>

⁶³ <http://etudesproject.org/>

- b. Stanford University⁶⁴ is conducting a feasibility study on developing automated tools for determining the copyright status of works published in the United States between 1923 and 1964.
- c. University of California⁶⁵ is developing tools to permit broader access to the world's leading libraries and other cultural institutions around the world.
- d. University of Michigan is developing and implementing Sakai,⁶⁶ a pre-integrated collection of open source tools, including a complete course management system, and a research support collaboration system.
- e. University of Southern California⁶⁷ is exploring a variety of social software tools and technologies to facilitate the use of Open Educational Resources.
- f. Western Interstate Commission for Higher Education⁶⁸ is developing tools that the higher education community needs to integrate online learning and the World Wide Web into teaching and learning.

2.2.7 OpenCourseWare Consortium

In February 2005, the first meeting of the OpenCourseWare Consortium was held at MIT. In the following two years the Consortium has grown in membership and substance at a rapid rate. It is now a collaboration of more than 120 higher education institutions (including a high ratio of leading universities) and associated organizations from around the world creating a broad and deep body of open educational content using a shared model. The mission of the OCW Consortium is to advance education and empower people worldwide through open courseware. Specific goals are to:

1. Extend the reach and impact of open courseware by encouraging the adoption and adaptation of open educational materials around the world.
2. Foster the development of additional open courseware projects.
3. Ensure the long-term sustainability of open courseware projects by identifying ways to improve effectiveness and reduce costs.

⁶⁴ <http://collections.stanford.edu/determinator>

⁶⁵ <http://www.cdlib.org/inside/projects/amwest/>

⁶⁶ <http://sakaiproject.org/>

⁶⁷ <http://www.annenberg.edu/projects/project.php?id=123>

⁶⁸ <http://www.edutools.info/>

We recommend a visit to the Consortium website⁶⁹ for a glimpse into this exploding world. The **Use** section lets you browse individual OpenCourseWare sites or search across all courses. The **Share** section discusses global, institutional, and faculty benefits for participation in OCW. The **Support** section describes how a variety of stakeholder types can participate. There are also tabs to a list of consortium members as well as recent news stories about OCW activities from around the world, many from major publications. The Consortium site, including for example access to the OCW How To Web site,⁷⁰ seems particularly useful to others who wish to learn how to join the OCW movement.

The most recent meeting of the Consortium covered topics such as a collective research agenda, sustainability, intellectual property best practices, OCW and national education policy, leveraging other OER resources for OCW, as well as the OCW portal structure and use. The next face-to-face meeting is scheduled for Spain in spring 2007.

We believe that a broad, grassroots-driven consortium of institutions in a variety of OER roles is important for enhancing the reach of OER in the direction we propose in Section 4. Although the OCW Consortium may be emerging as this asset, it is missing the participation of many of the major institutions now being supported by Hewlett under the OER program. These include Carnegie Mellon, Foothill–De Anza Community College District, Rice University, Stanford University, the Internet Archives, UC Berkeley and Yale. There are also other institutions in more specific roles that might be included. This raises the questions of what needs to be done to create a broader consortium attractive to a broader set of stakeholders and performers. How is the community being built by the OER investments going to be sustained and strengthened so it can seize an even larger opportunity for the collective good?

We caution, however, that more institutions and even more examples of any one course aren't necessarily better. How would we handle a "success disaster" in which, for example, a teacher now has access to 100 elementary calculus courses? We need incentives and mechanisms to promote creation and access to fewer instances of the same course but with more support material, more commentary, more examples, etc.

⁶⁹ <http://ocwconsortium.org/index.html>

⁷⁰ <http://ocw.mit.edu/OcwWeb/HowTo/index.htm>

2.2.8 International Impact

The OER program aspires to provide open access to (and eventually open contribution to) high-quality education resources on a global scale in many languages. The portfolio has supported a mix of provisioning high-quality OER, particularly in the United States, and its use worldwide, especially in developing countries. The impact is very impressive as measured by the international participation. The OpenCourseWare Consortium membership lists the huge consortium of Chinese institutions in CORE⁷¹ together with cadres of volunteers translating course material from English to Chinese. CORE now has over 100 university members with five million students. The ten lead universities use several hundred MIT OCW in their teaching programs. This has had a major impact on Chinese education. CORE also has about 150 Chinese courses on its website that can be shared globally.

International impact has been led by the OCW activities, but there has also been significant impact in the broader agenda of OER and ICT-supported learning beyond OCW. This impact has occurred through international projects such as Teachers Education in Sub-Saharan Africa (TESSA),⁷² Open University UK, Open University Netherlands, European Association of Distance and Teaching Universities,⁷³ India National Knowledge Commission⁷⁴ (through a grant to MIT), OECD,⁷⁵ and UNESCO International Institute for Educational Planning⁷⁶ (IIEP).

In France, we find the Paris Technology⁷⁷ “Graduate School,” a coalition of a dozen technical schools. The Japan OCW Consortium⁷⁸ includes ten universities. Universities in Spain and Portugal have rallied around Universia OCW⁷⁹ based largely upon MIT OCW material translated into Spanish.

Effectively involving Africa in OCW is a complex process. Hewlett has worked primarily through the African Virtual University, and MIT has worked directly with some additional schools in South Africa. The recent investment by Hewlett in the Open University⁸⁰ UK to enhance its participation in the OER movement, including access in Africa, is a good strategic move and may well leverage the excellent track record of the Open University in international engagement.

⁷¹ http://www.core.org.cn/en/news/2005/news_1202.htm

⁷² <http://www.tessaprogramme.org/>

⁷³ <http://www.eadtu.nl/>

⁷⁴ <http://knowledgecommission.gov.in/>

⁷⁵ <http://www.oecd.org/>

⁷⁶ <http://www.unesco.org/iiep/>

⁷⁷ <http://graduateschool.paristech.org/>

⁷⁸ <http://www.jocw.jp/>

⁷⁹ <http://mit.ocw.universia.net/>

⁸⁰ <http://www.open.ac.uk/>

One of the most enjoyable parts of reviewing the MIT OCW for Atkins was a dinner meeting in October 2005 with four MIT students who have participated in international engagements for OCW in West Africa as well as rural and urban China. The take-up of OCW resources in these different venues varies, but in all cases there is anecdotal evidence of positive impact. We were impressed with the power of the OCW as a means for cross-cultural engagement and with the life-changing impact that this experience has had on the students involved.

2.3 Major Remaining Challenges

2.3.1 Introduction

The portfolio of OER investments has created pilot projects within the strategic plan. The projects have demonstrated enthusiasm by the participants on both the production and consumption side but have also revealed challenges. In this section we comment on some of the most significant of these challenges. Each of these topics is complex, so we can do little more than state that further work is needed. Fortunately, there is a growing body of activity on each of these topics that the OER movement can leverage.

2.3.2 Sustainability

A challenge of any fixed-term, externally funded initiative is long-term sustainability by an entity other than the original investor, in this case the Hewlett Foundation. In the MIT project, bringing a course to the OCW costs approximately \$25,000 per course plus maintenance and enhancement. The MIT OCW model involves professional staff taking course material in almost any form from faculty and bringing it into a uniform, professional format. This was appropriate for the rapid startup of a large-scale, pioneering project but it will not work for many other places. It does appear, however, that MIT will be able to sustain the maintenance through internal funding and external contributions. Additional approaches to sustainability need to be explored, including the following:

1. Encourage institutions, rather than just individual pioneer-faculty, to buy into the OER movement so that institutional resources will be committed to sustain it.
2. Situate OER collections not as distinct from the courseware environment for the formally enrolled students but as a low marginal cost derivative of the routinely used course preparation and management systems. Increase the amount of course preparation and management systems that service closed and open institutional courseware.
3. Encourage membership-based consortia (along the lines of Internet 2) to distribute and to share cost and expertise.

4. Explore roles for students in creating, enhancing, and adopting OER. Consider an “OER Corps” in which students receive training, small stipends, and prestige to assist in material preparation, enhancement, and use (especially in historically disadvantaged domestic communities and developing countries).
5. Consider a voluntary (or mix of voluntary and paid) wiki-like model, in which OER is the object of micro-contributions from many. This approach raises complex issues of quality, but much work on collective “converging to better” is under way.
6. Examine ways that social software can be used to capture and structure user commentaries on the material. More generally, find ways to instrument the use of the material with special attention to capturing problems encountered by diverse student communities. Do the same for teachers using, remixing or repurposing the material.

Sustainability of OER is becoming a subject of academic study. Dholakia, King, and Baraniuk,⁸¹ for example, argue that current thinking on the topic is often solely tactical with too much attention on the “product” and not enough attention on understanding what its user community wants or on improving the OER’s value for various user communities. Their proposal is that “prior to considering different revenue models for a particular OER and choosing one or a combination of them, the OER providers should focus on the issue of increasing the aggregate value of the site to its constituents to the greatest extent possible. In other words, unless the OER site is able to first gain and maintain a critical mass of active, engaged users, and provide substantial and differentiated value to them in its start-up and growth phases, then none of the available and/or chosen revenue models will be likely to work for the OER in the long run.”

2.3.3 Curation and Preservation of Access

As digital OER content grows, so will the need for systematic reliable infrastructure for curating and preserving access. The Internet Archives has made pioneering contributions in this area. Fortunately, academic libraries and major and cultural heritage institutions, including the National Archives⁸² and the Library of Congress,^{83 84} are now giving more attention to preserving digital objects. As part of their mission, academic libraries^{85 86} are creating large digital repositories intended to be persistent. Similar activities are under way in the

⁸¹ What Makes an Open Education Program Sustainable? The Case of Connexion

⁸² <http://www.archives.gov/era/>

⁸³ <http://www.digitalpreservation.gov/about/planning.html>

⁸⁴ <http://www.digitalpreservation.gov/index.html>

⁸⁵ <http://www.lockss.org/lockss/Home>

⁸⁶ <http://dspace.org/federation/index.html>

U.K.⁸⁷ and European Union.⁸⁸ The White House Committee on Science has recently established an inter-agency working group on long-lived data to recommend approaches to scientific data object preservation in the government. The National Science Foundation has hosted several workshops⁸⁹ in this area and is leading cyberinfrastructure-enhanced discovery and learning. The NSF Office of Cyberinfrastructure⁹¹ is encouraging institutions to preserve and curate digital objects for scientific research and education. Google is also reportedly piloting a project for free hosting of large open collections of scientific data.

A growing number of initiatives concerning digital preservation and curation can be leveraged by the OER community. We suggest, however, that Hewlett be engaged in identifying needs and intentional in building partnerships in this area.

2.3.4 Object Granularity and Format Diversity

We use “digital object” or “digital learning object” as the building block of the OER corpus. Digital objects can be recursive—a digital object consists of one or more digital (sub)objects. By granularity, we mean the size of the objects that can be individually tagged, referenced, found, and re-used under appropriated attached terms and conditions. Is the entire document the smallest accessible/usable object (not decomposable), or can one access and use sub-components such as images, videos, simulation applets, etc? By “object format diversity” we mean the diversity of representations and encodings of digital objects (often signified by a file name suffix: .pdf, for example) and how this diversity effects interoperability between digital objects composed into more complex objects. We are not advocating the adoption of a single standard, especially as this is unlikely to happen. We are, however, noting the importance of accommodating heterogeneity in service of coherence. This is especially important in using mobile devices for delivery, as we will later advocate.

The starting point for OCW at MIT was a large, heterogeneous collection of faculty-produced and voluntarily contributed course material in diverse digital and non-digital formats. The .pdf file format was selected as the common denominator and continues to predominate. The choice of .pdf was the correct one at the time, but it needs to be re-examined. Use of .pdf limits the reuse of the material, especially a portion, or constituent objects, of a given document. Increased granularity of objects and increased accommodation of multimedia objects is desirable.

⁸⁷ <http://www.dcc.ac.uk/>

⁸⁸ <http://www.digitalpreservationeurope.eu/about/>

⁸⁹ <http://www.si.umich.edu/digarch/>

⁹⁰ <http://www.arl.org/info/events/digdatarpt.pdf>

⁹¹ <http://www.nsf.gov/oci/>

OER collections overall should migrate to richer document formats, preferably XML as the reference copy with automatic conversion to html, .pdf, and most any format handled by the http protocol; support embedded multimedia objects; and enhance access to sub-objects in documents. This will be increasingly important for translation into other languages and use on a variety of technology platforms.

2.3.5 Intellectual Property Issues

Intellectual property issues are at the heart of OER. The majority of existing educational content is protected under traditional copyright with terms and conditions that must be honored within the “open” paradigm. The formally defined faculty, staff, and student community of a university generally have access to site licensed digital materials through their library and have access to most of the literature that would be cited in course material. Students purchase access to other materials in textbooks and course packs. But in opening up course material to the world, institutions must invest the time and expense to scrub the material to be sure that materials licensed for use in their formal community are not available to world. The citation or link can be there, but the target cannot. Outsiders generally have access to abridged versions of the material although they may find the material elsewhere. As earlier described in Section 2.2.5, the Hewlett Foundation has wisely supported Creative Commons to help mitigate the constraints of “all rights reserved” copyright.

All of this is modulated by concepts of “fair use” and by an emerging spectrum of interpretation of copyright in the digital realm. The Google Book Search⁹² project, for example, is raising questions such as whether displaying excerpts of text around a hit from a key word search constitutes copyright violation, or indeed whether the initial digitization and indexing violate copyright. There are similar ambiguities occurring around the access to orphaned works, those under copyright for which an owner cannot be found at reasonable cost. The Copyright Office has recently completed a study of this topic and described several proposed “solutions.”⁹³

The legality of using traditionally copyrighted materials will evolve, hopefully in the direction of more openness, but the impact of OER will hinge on how widely the suite of licenses supported by Creative Commons are adopted. Present copyright law defaults to full copyright protection of a work; Creative Commons provides means of overriding that default. It is important that the OER-inclined education community continue to increase awareness and adoption of the Creative Commons culture to produce resources intended for use in open participatory learning ecosystems.

⁹² <http://books.google.com/>

⁹³ <http://www.copyright.gov/orphan/>

Although Creative Commons has done an excellent job of making the various license options “human readable” (as opposed to “lawyer readable”), this is complex stuff and could produce unexpected and unintended results. The MIT OCW uses the Creative Commons License 2.5 named Attribution-NonCommercial-ShareAlike 2.5.⁹⁴ David Wiley has recently drafted an article, “OpenCourseWars: A Partial History of Openness in Higher Education from 2005 – 2020,”⁹⁵ in which he paints a fascinating hypothetical trajectory for the OER movement triggered by litigation from industry violating the “non-commercial” attributes of the MIT OCW license. Also, as noted by Hal Abelson,⁹⁶ we are in an era in which it is very easy for students to record lectures or any downloadable class materials and broadcast them over the Internet. As we move more boldly into an era of remix and collaborative contribution we need to clarify legal and social practice concerning the rights of faculty. Do students have permission from the person who wrote or delivered a lecture to share it? And if so, how widely?

To help address issues such as this and many more, we understand that Hewlett will be providing additional support to the Creative Commons to help launch a new division, provisionally titled Learning Commons, which focuses specifically on education. The mission of Learning Commons is to break down the legal, technical, and cultural barriers to a global educational commons. To overcome technical and cultural obstacles, the Learning Commons will provide advice and expertise to the OER community and will identify lessons learned. Through partnerships and competitions, the Learning Commons will highlight successful and innovative uses and reuses of OER. All of this is important legal infrastructure for OER and beyond.

“Openness” is complex and not a black-and-white issue—a spectrum of degrees of resource openness is developing. The future holds opportunities and challenges for enriching and exploiting this spectrum.

2.3.6 Content Quality Assessment and Enhancement

The OCW movement has started with reputable institutions providing materials, thus ensuring their quality. Leading with MIT was key to the dramatic kick-off strategy and quick success. Providing high-quality materials from high-quality institutions will continue to be important, but they will increasingly be augmented by material from open resources, as is now occurring in the Connexions project. The grand challenge here is how we might close the loop on the use of open educational material so that we can create virtuous learning loops that constantly improve the material through use (and through

⁹⁴ <http://ocw.mit.edu/OcwWeb/Global/terms-of-use.htm>

⁹⁵ Will be a chapter in a pending book on Open Education to be published by MIT Press, david.wiley@usu.edu.

⁹⁶ See his recent HICSS presentation at http://www.hicss.hawaii.edu/hicss_40/apahome40.htm

the numerous learnings from remixes, etc.). Although some good work in this area has begun, it has barely scratched the surface, and we need to architect the next generation platforms to close the loop and accelerate the improvement of the material through reflected use.

A part of the solution is to replace traditional pre-publication review, often accept/reject and exclusive, with a post-publication review based on a more open community of third-party reviewers experienced in using the materials. In this model pre-publication credentialed materials are not merely distributed through the network; post-publication materials are credentialed through use in the network. We use material from a recent Connexions report, “Sharing Knowledge and Building Communities”⁹⁷ to make the point more vivid.

In Connexions, digital learning objects at different levels of granularity are contributed by many people into a “content commons.” Since the Content Commons is open to all, it will contain modules and courses in various stages of development and, hence, of various quality levels. How do we ensure that high-quality Connexions content is easily accessible to users? This requires both a means to evaluate and credential modules and a means to direct users to modules deemed of high quality.

⁹⁷ The Connexions working paper is available from Richard Baraniuk (richb@rice.edu). Also see <http://www.cni.org/tfms/2001b.fall/handout/Connexions.RReedstrom2001Ftf.pdf>

Rather than make a single pre-review accept/reject decision regarding each module, Connexions opens up the editorial process to third-party reviewers and editorial bodies for post-review. While Connexions users will have access to all modules and courses in the Content Commons (whatever their quality), users will also have the ability to preferentially locate and view modules and courses rated high quality by choosing from a range of different lenses provided by third parties. Each lens has a different focus. As a simple example of a lens, imagine a professional society independent of Connexions, such as the American Physical Society, that sets up a Web page containing a list of all physics Connexions modules and courses that it deems high quality. It can also post reviews of those modules and courses. The list would prove indispensable to students and instructors who trust the opinions of this society. Indeed, users will be able to configure their Roadmap browser to view preferentially those modules approved by the editorial bodies of their choice. Of course, users will always have the option of turning off all “lenses” to view the commons in its entirety.

The lens analog used above and other related methods for future use derive from a growing body of research on collaborative filtering,⁹⁸ recommender systems,⁹⁹ and reputation systems.¹⁰⁰ The same idea has also been explored in the PICS system¹⁰¹ to support Internet access control without censorship.

A relevant recent development is *Nature* magazine’s experiment with open peer review.¹⁰² In the trial, the papers selected for traditional peer review were, in a parallel option offered to authors, hosted for public comment. In the event, 5 percent of authors took up this option. Although most authors found at least some value in the comments they received, they were few, and editors did not think they contributed significantly to their decisions.

The disappointing aspect was not the author participation (which was in line with our expectations) or general levels of interest and web traffic (both good), but the number and average quality of the comments. So (1) open peer review doesn’t work, (2) the particular approach they used doesn’t work, or (3) scientists aren’t ready for it yet. The trial results alone don’t allow us to tease

⁹⁸ <http://www.si.umich.edu/~presnick/papers/cscw94/>

⁹⁹ <http://www.acm.org/pubs/cacm/MAR97/resnick.html>

¹⁰⁰ <http://www.si.umich.edu/~presnick/papers/cacm00/index.html>

¹⁰¹ <http://www.w3.org/PICS/iacwcv2.htm>

¹⁰² <http://www.nature.com/nature/peerreview/index.html>

apart these possibilities, but our bias (in agreement with the author of this blog item¹⁰³) is to favor (3) and perhaps (2), rather than (1).

2.3.7 Computing and Communication Infrastructure

Everything we have been describing is based on a platform of distributed computing and communication technology, a.k.a. *e-infrastructure*¹⁰⁴ or *cyberinfrastructure*.¹⁰⁵ We assume continued advances in this area are driven in part by continuing exponential gains in computation and communication rates and storage capacity. “Hundred dollar laptops”¹⁰⁶ and “one laptop per child”¹⁰⁷ activities are growing. The capacity of international networks for education and research is growing and reach through the leadership of the U.S. National Science Foundation and their international counterparts.¹⁰⁸ (Significant progress has been made recently in Latin America, and there is some reason for optimism in better networking to sub-Saharan Africa although much remains to be done, especially within countries.) But access to the supporting technology, especially, but not exclusively, in the developing world cannot be taken for granted.

One of us, Hammond, has extensive on-the-ground experience with information and communication technologies (ICT) in developing regions and with new technologies and trends that could be important within five years. These may be ripe for testing and for exploratory investments by Hewlett in support of OER and the next phase we are calling OPLI. There is more on this topic in section 3.2.3. In the Appendix to this report is a paper by Hammond, “The Realities of Information and Communication Technology in Developing Region and Implications for OER Initiatives.” It makes a strong case for mobile phone technology.

The experience with basic connectivity in the developing world is that the first step is far more transformative than the same (incremental) step in our developed world, and education in emerging economies is in the mainframe era, not even the PC era, so mobiles (situation-aware, portable, always-on devices) have the potential to be equally transformative in the developing world.

2.3.8 Scale-up and Deepening Impact in Developing Countries

A primary goal of the Hewlett Foundation Open Educational Resources Initiative is to use information technology to help equalize access to knowledge

¹⁰³ http://blogs.nature.com/wp/nascent/2006/12/nature_open_peerreview_trial_c.html

¹⁰⁴ http://www.jisc.ac.uk/whatwedo/programmes/programme_einfrastructure.aspx

¹⁰⁵ http://www.nsf.gov/publications/pub_summ.jsp?ods_key=cise051203

¹⁰⁶ <http://laptop.media.mit.edu/>

¹⁰⁷ <http://www.laptop.org/>

¹⁰⁸ <http://www.irnclinks.net/>

and educational opportunities across the world. The initiative targets educators, students, and self-learners worldwide. The impact on the developing world has been solid but modest with respect to the need. The scale of resources invested by Hewlett and others and the scale of pilot deployments, experimentation, and development of indigenous institutional participation in the OER movement, does not begin to match the scale of the unmet needs in the developing world for digital access, availability of high-quality educational content, or interactive (as opposed to rote learning) educational processes. The challenge here is immense, but so is the potential impact.

There are interesting questions as to the definition of “developing country” that may affect Hewlett’s future priorities. The real division is not country by country, but modern urban versus rural. Parts of China, India, South Africa, Brazil, Mexico, and usually at least the capital city in most other developing countries have a modern urban core, where broadband and other business services are available, at a price, and where the small middle class and the technical elite can be found, at least during working hours. The rural areas of all these countries are still very poor, unconnected in any systematic way, and unprepared for being pushed into a cash-based global economy (although it’s happening anyway). Since substantially more than 50 percent of both China and India’s populations are rural and have incomes below \$3 U.S. a day, they could be called developing countries—even if at the national governance level, these nations are quite powerful modern states. South Africa is similar.

Brazil and Mexico and Russia are tougher calls, because they are 70 percent or more urban and have higher average incomes, but the rural areas (and the urban slums) are still “developing.” Most of the development literature treats all of these countries as developing, even while acknowledging a growing modern urban core. It is the modern urban–rural disparity, in fact, that is the greatest source of potential social instability—and the governments know it.

There is hunger among ordinary people to learn English better, to improve their business skills, to learn how to do specific technical tasks that improve their employability—whether you call it an unmet need or an untapped market, it is substantial. An educational approach that is informal (outside of schools), self-paced, interactive, voluntary, group-based, and visual can fit into a long bus ride or standing in line or a slow day at the market stall—the real circumstances of people in developing markets.

We leave this topic with a startling set of observations by Sir John Daniels,¹⁰⁹ currently President and CEO of the Commonwealth of Learning in Canada, and formerly Vice-chancellor of the Open University, UK.

¹⁰⁹ <http://www.col.org/colweb/site/pid/2833>

- Half of the world's population is under twenty years old.
- Today, there are over thirty million people who are fully qualified to enter a university, but there is no place available. This number will grow to over 100 million during the next decade.
- To meet the staggering global demand for advanced education, **a major university needs to be created every week.**
- In most of the world, higher education is mired in a crisis of access, cost, and flexibility. The dominant forms of higher education in developed nations—campus based, high cost, limited use of technology—seem ill-suited to address global education needs of the billions of young people who will require it in the decades ahead.

3 The Brewing Perfect Storm

3.1 Introduction

The Hewlett Foundation has been a major force in creating an OER movement that will yield benefit into the future even if Hewlett now exits the field. But doing so would forfeit an extraordinary opportunity and responsibility to leverage its investments to both deepen and broaden the impact of the OER initiative.

We are advocating investments to achieve more pervasive access to OER and are advocating an initiative aimed at deeper impact on *learning*. We advocate an initiative, building on OER, to create a global *culture of learning*. A *culture of learning*, or what some might call a *learning ecosystem*,¹¹⁰ is targeted at preparing people for thriving in a rapidly evolving, knowledge-based world. This world demands creativity, innovation, and entrepreneurialism from all of us. This approach is very much in the spirit of what Marshall Smith and Catherine Casserly are saying in the context of their talks with titles like “The Old and the New: A Learning Revolution,”¹¹¹ in which they focus not on marginal change in the educational system and school, but rather on ways to use technology to create powerful improvements in learning. For example, wireless and mobile phone technologies offer new opportunities for OER access, especially in the developing world.

The OER initiative has been a vehicle for building a culture of sharing. We now propose that OER be leveraged within a broader initiative—an international **Open Participatory Learning Infrastructure (OPLI)** initiative (to be described in Section 4) for building a culture of learning.

This is a risky undertaking, but we believe that conditions now exist to make it compelling. In this section we survey threads of activities that, like OER, are individually significant but if combined together would be far more powerful. Figure 4 illustrates a framework of enablers, transformative initiatives under way and proposed, and grand challenges that are elements of a possible perfect storm of innovation in discovery and learning.

¹¹⁰ Further consideration in the future of the analogs between a learning ecosystem and a natural ecosystem may be productive. Ecosystems are characterized by interdependency, diversity, complex composition, variation in granularity and scale, adaptive (plastic), and evolving. Other important concepts in ecosystems are key species, energy cycles, key elements, and food webs.

¹¹¹ http://www.ced.org/docs/report/report_ecom_openstandards.pdf

The key **enablers** we focus on are

- open source code, open multimedia content and the community or institutional structures that produce or enable them;
- the growth of what we are calling participatory systems architecture;¹¹²
- the continuing improvement in performance and access to the underlying information and communication technology (ICT);
- increasing availability and use of rich media, virtual environments, and gaming; and
- the emerging deeper basic insights into human learning (both individual and community) that can informed and validated by pilot projects and action-based research.

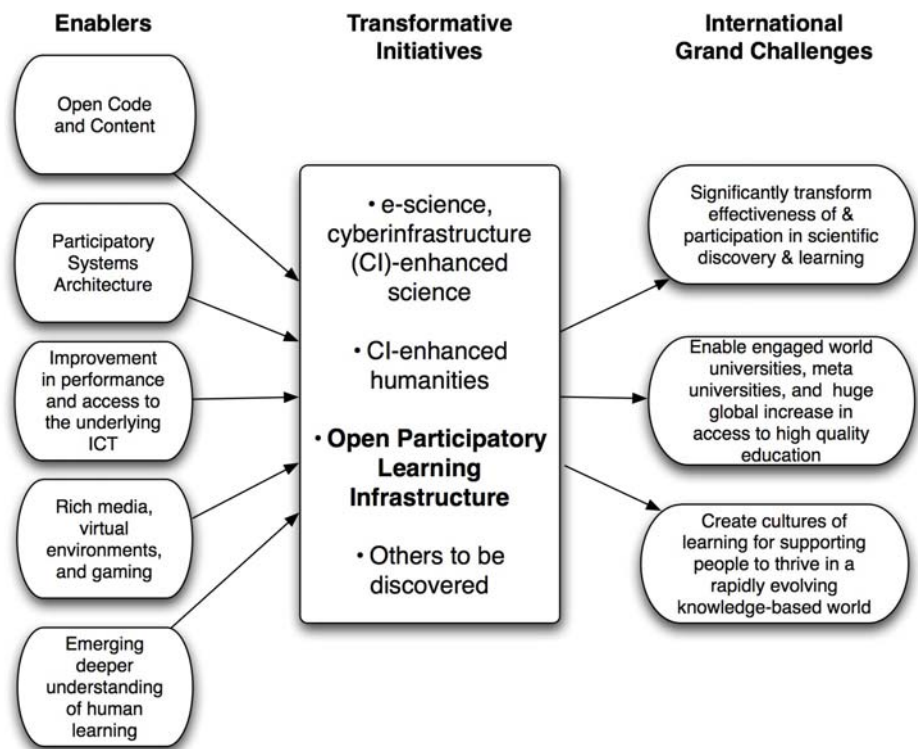


Figure 4—Enablers and collateral initiative context for the OPLI Initiative

These enablers are already empowering major domestic and international transformative initiatives in science and engineering research and education (e-science, a.k.a. cyberinfrastructure-enhanced science) and salients of innovation

¹¹² Our notion of architecture includes both technical and social dimensions.

in the humanities. The e-science activities are directed at meeting grand global challenges through more effective science and engineering, at enhanced innovation, and at maintaining leadership in a global knowledge-based economy. A spin-off of the science-focused cyberinfrastructure activities has been a growing focus on the role of technology in enhanced scholarship and learning in the humanities and social sciences. All of this is fueling reflection about augmented models of the university of the future, including the concepts “engaged universities in and of the world” and “meta-universities¹¹³.” And we are proposing that Hewlett lead a complementary “open participatory learning infrastructure” initiative. In Figure 4, we also suggest that Hewlett will be able to identify and leverage other initiatives in the world yet to be discovered. There is huge potential synergy between these initiatives and the challenges they are targeting to meet.

So we are situating the proposed OPLI with other **transformative initiatives**, empowered by common enablers, that like the OER, are well under way and potentially highly synergistic, namely

- the worldwide e-science movement, or what is called in the United States cyberinfrastructure (CI)-enabled science;
- the less developed and funded, but potentially high-impact movement concerning CI-enhanced humanities.

These initiatives are all in service of meeting international, strategic societal **grand challenges**, namely

- to significantly transform effectiveness of and participation in scientific discovery and learning;
- to enable engaged world universities, meta universities, and a huge global increase in access to high-quality education; and
- to create cultures of learning for supporting people to thrive in a rapidly evolving knowledge-based world.

We believe that the Hewlett Foundation in concert with other investors and stakeholders could make a major contribution by defining and leading the OPLI initiative and linking with the other two initiative areas in ways that contribute to meeting all three of the grand challenges. In the remainder of this section we elaborate on the elements of the framework in Figure 4.

¹¹³ Charles M. Vest, “Open Content and the Emerging Global Meta-University,” *EDUCAUSE Review*, May/June 2006, <http://www.educause.edu/apps/er/erm06/erm0630.asp?bhcp=1>

3.2 Enablers

3.2.1 Open Code and Content

The power of open source code and open source development communities is now legendary. *Open source* actually includes three complementary dimensions: (1) intellectual property policy, (2) virtual distributed collaboration, and (3) community governance models. These practices and methods that have given us Linux, the Apache Webserver (70 percent of the server market), and the FireFox (2nd most used) web browser can be generalized so they can be used for the creation and community-based iterative enhancement of more broadly defined digital objects. This is being explored, for example, in the Connexions project. Closely related are the concepts of mashup and remix. Mashup refers to producing digital applications or media through rather straightforward linking of other building blocks such as Google map or Google Earth. The approach empowers people without good programming skills to tailor and innovate. Remix is processing an existing object, for example a song, to create an alternate from the original model. Another virtuous cycle in all this is that open source software is increasingly providing effective infrastructure for access to open content and participation. Plone¹¹⁴ and Zope¹¹⁵ are open source community platforms for building web services, and Truphone,¹¹⁶ Rebtel,¹¹⁷ and jajah¹¹⁸ are open source codes supporting free voice over IP.

We need not dwell on the fact that the high-quality open courseware movement is part of a bigger movement in web-based open content of extreme variable quality. A sign of the times is that the CIO Council of the federal government is now pushing a transition from *need to know* to *need to share*. Perhaps most relevant is the movement toward more open forms of scholarly communication—the authoring, review, publication, and access of academic works. This movement is prompted by several factors including: a backlash against escalating pricing and restricted terms of use of scholarly journals, the need for academic libraries to steward the growing digital content assets of their community, a belief that knowledge created with public funds should be freely available to the public, and interpretations of the fundamental mission of university to be sharing knowledge with the world.

Less well understood but potentially of huge relevance to the OER movement are the processes whereby resources are contributed, mixed, enhanced, and redistributed—in which less-than-high-quality materials are revised and improved and become part of something much better. The Web 2.0

¹¹⁴ <http://plone.org/>

¹¹⁵ <http://www.zope.org/>

¹¹⁶ <http://www.truphone.com/scn/>

¹¹⁷ <http://www.rebtel.com/rebtel/>

¹¹⁸ <http://www.jajah.com/>

phenomenon is converting consumers to producers and supporting a huge outpouring of creativity in user-generated content. “Collective intelligence” is helping us organize huge masses of information through, for example, “folksonomies.” Amateurs are doing the work of professionals, or amateurs and professionals are working together through “crowdsourcing.” The “long tail” is providing consumers much wider distributions of choices, be they books, rare ceramics, or courseware on obscure topics. How can all of this and more be applied to learning in an OER world as participatory architectures become more pervasive and powerful?

Open code and content are part of a larger openness movement that may be relevant to the future of OER and beyond. “Openness” has become a subject of substantial interdisciplinary academic study with growing expertise that could be called upon by the Hewlett Foundation. Openness includes development and adoption of *open standards* and *open innovation*¹¹⁹ in the world of the firm. Open innovation involves limited open sharing between firms for some collective good (cooperate to compete) but not necessarily for the public good. We also note that openness of product and/or process leads to enhanced opportunities for openness in monitoring evolution and impact as well as more openness in understanding impact. This is a very important attribute of openness to which we will return in Section 4.

3.2.2 Participatory Systems Architecture

The rapid emergence of the World Wide Web, layered on the Internet and distributed computing architecture, is the mainstay for provisioning and using open educational resources. In its first phase, the web has been used largely to distribute information. It has now emerged as a platform for collaboration and participation in a wide variety of collective activities. It has been used as a platform for what is often generically called social software.¹²⁰ It has entered the “web 2.0” phase—a shift from information to participation. This creates a platform for the OPLI Initiative we are advocating.

What we are calling *participatory systems architecture* underlies the *TIME* Person of the Year being **You**. Quoting from the *TIME* story,¹²¹

¹¹⁹ Concept pioneered by Henry Chesbrough. See <http://www.openinnovation.net/>

¹²⁰ http://en.wikipedia.org/wiki/Social_software

¹²¹ *TIME* magazine, December 25, 2006. See cover story at [http://www.time.com/time/magazine/article/0,9171,1569514,00.html?aid=434&from=o&to=http percent3A//www.time.com/time/magazine/article/0 percent2C9171 percent2C1569514 percent2C00.html](http://www.time.com/time/magazine/article/0,9171,1569514,00.html?aid=434&from=o&to=http%20percent3A//www.time.com/time/magazine/article/0%20percent2C9171%20percent2C1569514%20percent2C00.html)

The new Web is a very different thing. It's a tool for bringing together the small contributions of millions of people and making them matter. Silicon Valley consultants call it Web 2.0, as if it were a new version of some old software. But it's really a revolution.

It also resonates with the earlier *TIME* cover feature, “How to Build a Student for the 21st Century,”¹²² including references to “Learning 2.0.”

The concept of Web 2.0 is still evolving, although the term is in wide use (96.6 million hits on the term “Web 2.0” in Google). A good overview is available at the O’Reilly website;¹²³ from that article we have borrowed Figure 5 to give the reader a general flavor of the attributes of Web 2.0. A short video entitled “Web 2.0 – The Machine is Us/ing Us” available at the YouTube site conveys a visual impression of what “Web 2.0” implies¹²⁴.

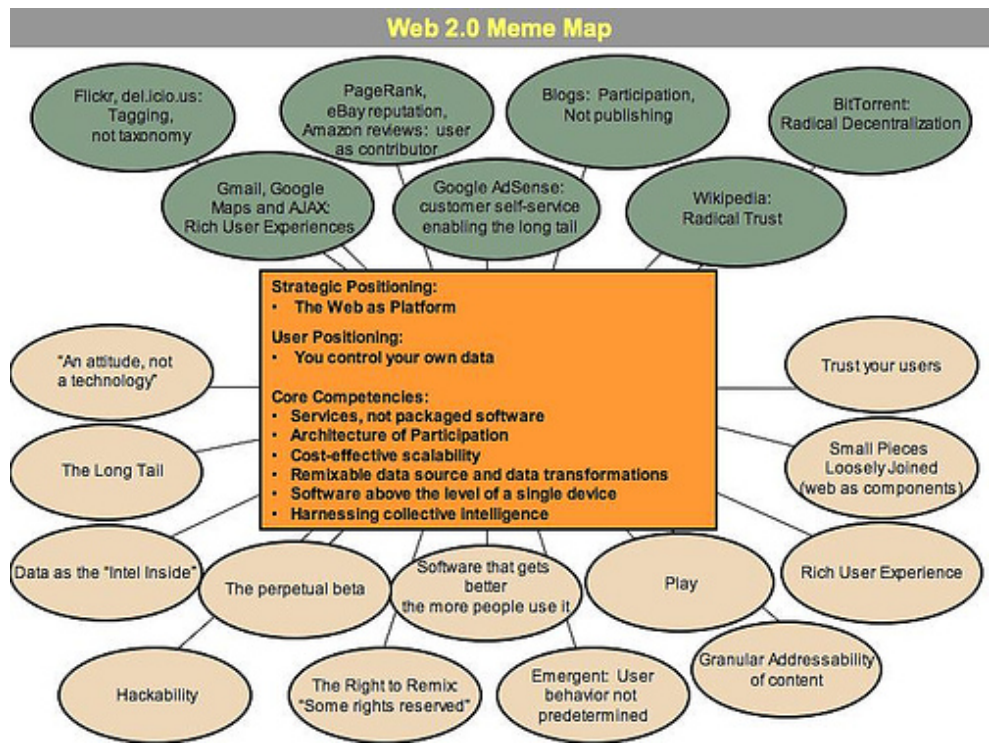


Figure 5—Attributes of Web 2.0 (from <http://www.oreillynet.com/pub/a/oreilly/tim/news/2005/09/30/what-is-web-20.html>)

¹²² *TIME* magazine, December 18, 2006, pp. 50-56.

¹²³ <http://www.oreillynet.com/pub/a/oreilly/tim/news/2005/09/30/what-is-web-20.html>

¹²⁴ <http://www.youtube.com/watch?v=6gmP4nk0EOE>

There are other threads of activity that will empower the OPLI initiative including:

- The three-decades-old research and development knowledge base of the computer-supported cooperative work (CSCW) community.¹²⁵
- The increasing prevalence of “service-oriented architecture” that among other things is a paradigm for discovery and re-use of software objects and for organizing and using distributed capabilities that may be under the control of different ownership domains.¹²⁶
- Initiatives of the Mellon Foundation,¹²⁷ Moore Foundation,¹²⁸ Getty Foundation, and others to create open source software services and middleware for academic enterprise, including international virtual communities. They are now considering scholarly middleware, workflow engines, user interfaces (especially for accessibility in the FLUID project), and software bus initiative for academia that may directly support OPLI.
- The Second Life¹²⁹ phenomenon—an open-ended virtual world created by San Francisco–based Linden Lab. Second Life gives its users (referred to as residents) tools to shape its world. Second Life combines features from social networks, multiplayer online games, and e-tailers; it lets people adopt new personas called avatars in its 3D world, where they can interact with others for entertainment and business purposes. Millions of dollars exchange hands every week in member-to-member commerce in Second Life. Companies including IBM, Dell, Starwood Hotels & Resorts Worldwide, and American Apparel are setting up shop in Second Life to sell and promote their services.
- Research, development, and deployment of numerous virtual organizations in international e-science/cyberinfrastructure initiatives, including those supported by the U.S. National Science Foundation (NSF). Figure 6 illustrates the virtual organization framework for the NSF activities and some of the various names for such organizations in use by international distributed research communities.

¹²⁵ <http://www.cscw2006.org/index.html>

¹²⁶ http://en.wikipedia.org/wiki/Service-oriented_architecture#SOA_definitions

¹²⁷ <http://rit.mellon.org/>

¹²⁸ <http://www.plos.org/about/index.html>

¹²⁹ <http://secondlife.com/>

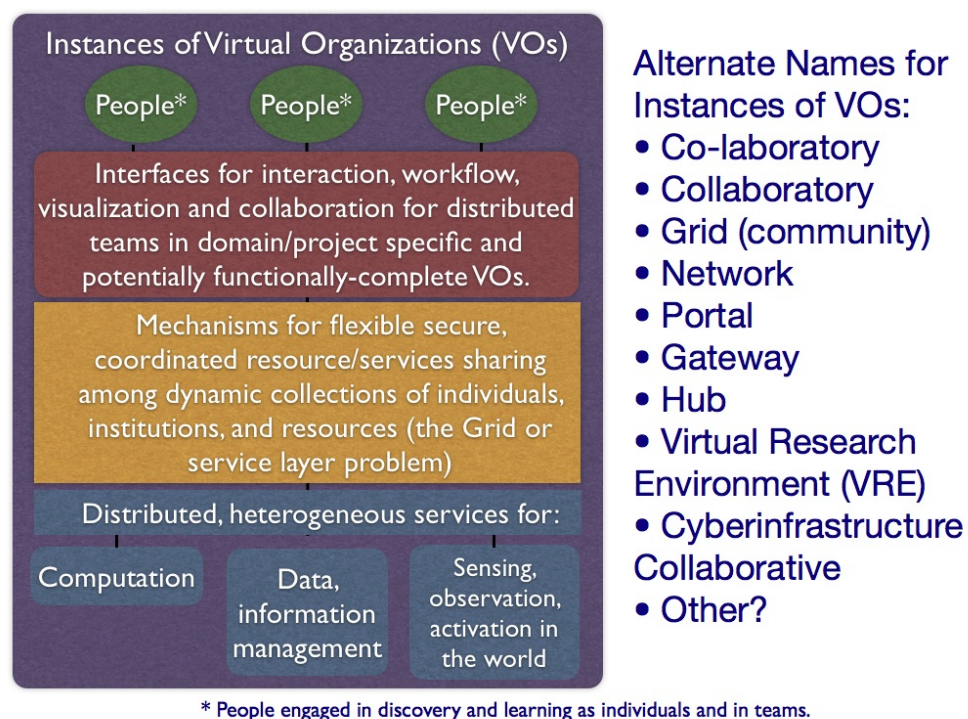


Figure 6—Framework for virtual organizations for distributed participation in science.

3.2.3 Improvement in Performance and Access to the Underlying ICT

The exponential improvement in computation rates, information transfer rates, and storage capacity continues. This is manifest in both increased capacity for fixed dollars and decreased cost for fixed performance. Increased capacity, now approaching the “petascale¹³⁰ regime,” is critical to e-science. Reduced cost and thus ubiquity of access is critical for an international OPLI initiative.

Eventually, however, the increased power of computing that is opening new frontiers for simulation, modeling, and virtual/augmented reality will be highly significant for open participatory learning. Of all these improvements in computation, storage, and networking, the most important is networking—the *ability to connect*.

Cell phones, particularly as they become “smarter,” offer a promising platform for massification of education participation in developing countries. We are recommending that Hewlett place a large emphasis on exploring access to OER and participatory learning through mobile devices. In developing countries, adoption of mobile phones far exceeds adoption of PCs, and the trend is, if anything, accelerating. The reasons are partly economic: phones are less

¹³⁰ Petascale means computations rates greater than or equal to 10^{15} operations per second.

expensive, are offered with affordable pay-per-use service models, and offer immediate livelihood and welfare benefits. But the utility of voice, the appeal of digital photography and video, and widespread illiteracy or semi-literacy favor phones as well. As a result, close to 2.5 billion people in developing countries will own a mobile phone within five years, and a larger number will have shared access to a phone, a potential “market” for massification of education in both school and non-school contexts.

Phones are evolving technologically as well, gaining e-mail, web-browsing, video, and Wi-Fi or other broadband Internet access capabilities. Within five years, the typical mobile phone is likely to have the processing power of today’s PC. Thus for the vast majority of people in developing countries, their PC and Internet access device will be a mobile phone, a handheld computer or a hybrid of these devices, such as the new Apple iPhone, whose high-profile marketing efforts and design qualities are likely to spur momentum, competition, and a great deal of attention. At the moment, this phone-PC convergence is concentrated on high-end users and high prices, but that is likely to change well within five years, driven in part by the huge volume of potential users in developing countries.

Hence it is important for Hewlett to consider how this platform, with its emphasis on voice, images, video, and interactive short messaging, can serve the needs of education. How should the commercial approach translate to this new platform? Should broadband phones function simply as a source of connectivity for traditional classroom curricula, or can they play a broader role, enabling more interactive educational approaches? How can industry take advantage of the widespread use of mobile phones to deliver educational resources—including language training and courses in basic technical skills such as accounting, outside the classroom environment—enabling a wider group of people to upgrade their employability?

We encourage the reader to also read the paper by Hammond in the Appendix, “The Realities of Information and Communication Technology in Developing Region and Implications for OER Initiatives.”

3.2.4 Rich Media, Virtual Environments, and Gaming

Students growing up digital approach learning quite differently from prior generations. Yes, their attention span is limited, but their multitasking capabilities allow them to switch contexts nearly instantly. They are comfortable with jumping into a situation or a topic not knowing ahead of time what they need to know to succeed. In that sense, they expect to discover or uncover knowledge as they explore a domain. They don’t expect to be told by an authority to read a manual. Sink or swim is their coin of the day. Although this sounds chaotic, they use social resources and the Net to navigate their way through a complex situation. They learn from and with their peers as much as

from standard sources of authority. They are inherently collaborative learners who want to learn by doing. This process of doing plays out across nearly all the disciplines. They build, they remix, they mod, they blog, they converse, they share hints, stories, writings—all facilitated by digital communication in both physical and virtual worlds.

It is easy to dismiss the more subtle aspects of their activities. Take games, especially massively multiplayer games. What is being learned here? First of all, notice that playing a game such as the popular World of Warcraft (WoW) requires a player to find, join, or form a guild of like-minded players. The social skills to build and maintain guilds are non-trivial, and success depends on developing this skill. Players also develop dispositions that increase their situational awareness to make sense out of what is happening around them. Most learning here happens experientially, often from their making decisions and having to live with and reflect on the consequences.

Let's briefly consider two games that aim at getting kids more engaged in civic affairs. The first is the PeaceMaker¹³¹ at CMU that presents a crisis between Israel and Palestine and gets teams to play both sides in terms of what Israel and Palestine should do. Depending on the move, each team gets to experience the likely reactions by the various constituents they represent, letting one experience how fast a situation can become critical. What emerges from playing this game is a skill in understanding opposing positions.

Another game of this genre is under development at the University of Southern California by Doug Thomas and Chris Swain: the Redistricting Game.¹³² As Thomas describes it, "The purpose of the game is to provoke engagement around issues of political redistricting, reapportionment, and gerrymandering. The potential of this game is not in educating people about the ways in which redistricting works, though it does do that. The true potential is in what happens around the table when people play it. When players engage with the game and each other, they enter into a grounded discussion that forces them to think critically about the choices they make and well as engage in critical reflection about the processes in which they are engaged."

The NSF is now investing in projects to explore online multiplayer, role-playing games in an immersive 3-D environments. One example is WolfQuest¹³³ in which players join a wild wolf pack and venture into the wilderness. Playing alone or in teams in multiplayer missions, they join a wolf pack and hunt, fight, and socialize, all while doing their best to survive. The WolfQuest experience goes beyond the game with an active online community where you can discuss

¹³¹ <http://www.peacemakergame.com/>

¹³² <http://redistrictinggame.org/>

¹³³ <http://www.wolfquest.org/>

the game with other players, chat with wolf biologists, and share artwork and stories about wolves.

These examples barely scratch the surface in some of the unusual ways these immersive environments provide new opportunities for creating powerful experiential learning environments. But the design of such environments transcends standard pedagogy and theories of learning based on direct transfer. Such environments, especially ones that combine the social with the experiential, can be used to powerfully augment more traditional learning modes and materials.

Immersive environments such as Second Life¹³⁴ enable users to create their own avatars and have their avatars participate in a virtual space such as a classroom or amphitheater or replica of some archeological/architectural site under study. This opens up quite a new opportunity for distributed, distance learning by creating a sense of co-presence among the users allowing all kinds of natural interactions among themselves or between themselves and the speaker. It is now even possible to do a simulcast from a physical setting into the virtual setting, allowing a distributed set of students to join a physical class or gathering.

3.2.5 Emerging Deeper Understanding of Human Learning

Many traditional theories of pedagogy have focused on the best ways to transfer knowledge from the teacher to the student. More recent theories have focused on ways to help students internalize that information in a way that makes it both personally meaningful and applicable to new situations. New computer-enhanced learning environments have played a significant role in accelerating this internalization process. For example, in training simulators for complex, real-time decision-making, AI-based automated tutors are used skillfully for after action reviews to get the student to reflect on questionable decisions. In a similar manner, CMU in its OLI have led the way in getting intelligent tutoring systems to watch over the shoulder of students solving homework problems in physics and steer them back on a useful path when they wonder too far astray. Acuitus¹³⁵ is now testing an AI-based tutoring system for teaching Navy personnel how to become expert network administrators and troubleshooters. This system includes a structure motivation model for governing the tutor, keeping it from speaking too much or too little, along with a model of tutoring inferred from studying master tutors. The initial results of this system indicate that it outperforms the best human tutors and reportedly reduces time to mastery by 60 percent or more.

¹³⁴ <http://secondlife.com/>

¹³⁵ <http://www.acuitus.com/web/curieIndex.html>

Building models of tutors is only one of the dimensions at stake here. We need also to consider models of the knowledge domains and how they become embedded in simulations, visualizations, and serious games. For example, the Federation of American Scientists (FAS) in conjunction with Brown University and USC has built Immune Attack,¹³⁶ a game that models our immune system.¹³⁷ The game lets students control immune cells, battle disease, solve infections, etc. The game takes place in the bloodstream much like in the science fiction film *Fantastic Voyage*.¹³⁸ Another example of “getting a feel for” a subject domain involves new deeply immersive 3-D visualization of protein folding that allows student to walk inside a protein—using an immersive cave—and to touch and explore proteins.¹³⁹

It is hard to imagine more powerful experiential learning than these above, but this is barely scratching the surface of what is coming. For example, above we talked about the Redistricting Game. Though the game is not yet computer mediated, the conversations it evokes reveal how a small number of personal experiences can impress a player with how political systems are judged as being fair or not, even if they remain within the rules’ allowable actions.

All these examples point to expanding learning theories that include situated learning and *learning-to-be* (within an epistemic frame) rather than just *learning-about*. The stage is being set to reformulate many of Dewey’s theories of learning informed by and leveraging newer cognitive and social theories of learning and delivered in computationally rich experiential learning environments.

3.3 Other Complementary Transformative Initiative Areas

These enablers and others are already powering initial transformations in the *who*, *what*, and *how* learning and discovery is done: OER, e-science/CI-enhanced science, and CI-enhanced humanities. We suggest that the Hewlett Foundation build on its leadership in OER and build bridges to these other complementary movements. The e-science initiatives will benefit from the complementary focus on open learning, and the open learning initiatives will benefit from the focus on discovery and the financial investments going into e-science. There is huge potential synergy.

¹³⁶ <http://www.fas.org/immuneattack/>

¹³⁷ The FAS has also recently issued a report from a *Summit on Educational Games*, available at <http://fas.org/gamesummit/>.

¹³⁸ http://en.wikipedia.org/wiki/Fantastic_Voyage

¹³⁹ Until a few years ago this required millions of dollars of computing but now by using cluster computing and a set of nvidia game boards these visualizations can be rendered in real time.

3.3.1 E-science and Cyberinfrastructure

There are now major e-science, cyberscience, or cyberinfrastructure-enhanced science initiatives under way in most every developed region of the world. Cyberinfrastructure (CI), or e-infrastructure, refers to computer and communication technology–based resources (tools, services, information) together with the people and institutions supporting them. Specific collections of these resources, accessed over networks, are configured to support distributed communities through web portals and workflow interfaces to provide the computation, knowledge management, observation, and collaboration tools needed by a specific team, project, discipline, or community of practice. Such distributed organizations go by many names (as listed in Figure 6). Science often needs the highest capacity computer, the highest bandwidth networks, and the largest data storage capabilities available, so they are often harbingers for what will be in general use in the future.

The U.S. National Science Foundation in particular has taken the lead for the United States in creating and executing “NSF’s Cyberinfrastructure Vision for 21st Century Discovery.”¹⁴⁰ This document begins with a bold call for action as follows: NSF will play a leadership role in the development and support of a comprehensive cyberinfrastructure essential to 21st-century advances in science and engineering research and education. It goes on to describe a vision of comprehensive CI-enhanced science and engineering education based on high-performance computing, knowledge management, observatories, virtual organizations, and supporting programs of education and workforce development. The impact of cyberinfrastructure is also prevalent in many parts of the new NSF strategic plan: Investing in America’s Future.¹⁴¹ NSF has established a new high-level Office of Cyberinfrastructure (OCI) to coordinate strategic programs of investment and is committing about \$700 million per year toward this goal. There are similar large and growing activities in the United Kingdom, the European Union,¹⁴² Canada, Australia, New Zealand, South Africa, Japan, China, Taiwan, and Korea, and growing international cooperation.

Although “open” is not in the name of this movement, most all of the software and much of the content and data emerging from the e-science/CI movement is open in the sense of OER openness. Furthermore, it extends the notion of “open resource” to not only course content, but also to a huge web of scientific data and online instrumentation (sensor networks, observatories, fabrication

¹⁴⁰ <http://www.nsf.gov/od/oci/ci-v7.pdf>

¹⁴¹ <http://www.nsf.gov/pubs/2006/nsf0648/nsf0648.jsp>

¹⁴² Distributed knowledge communities enabled by virtual organizations are a key part of the strategy for linking education, research, and education in the new European Union Framework 7 for their Information Society.

facilities). It empowers great emphasis on authentic, practice-based learning—on *learning to be*.

We emphasize an important fact: this is a grassroots, bottom-up, movement coming from the research communities. It is not a top-down, blue-sky initiative thought up in Washington. The community-driven nature of this movement is evidence of readiness for transformation toward a new culture of learning and discovery, at least in the sciences and engineering.

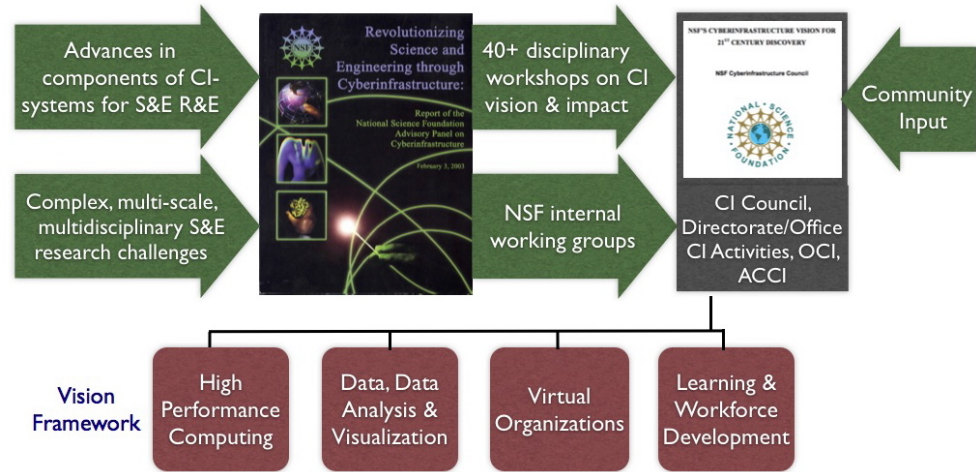


Figure 7—NSF CI vision and activities based on broad and diverse community engagement.

As illustrated in Figure 7, this movement was catalyzed by a landmark 2003 report from an NSF-appointed Blue-Ribbon Advisory Panel, “Revolutionizing Science and Engineering through Cyberinfrastructure.”¹⁴³ This report includes the following assertion:

“a new age has dawned in scientific and engineering research, pushed by continuing progress in computing, information, and communication technology, and pulled by the expanding complexity, scope, and scale of today’s challenges. The capacity of this technology has crossed thresholds that now make possible a comprehensive “cyberinfrastructure” on which to build new types of scientific and engineering knowledge environments and organizations and to pursue research in new ways and with increased efficacy.”

¹⁴³ <http://www.nsf.gov/od/oci/reports/toc.jsp>

Since this report was issued, there have been several dozen national and international workshops and reports from all branches of science and engineering, research, and education exploring the implications of cyberinfrastructure for their future. Many of these reports are available through the NSF OCI website.¹⁴⁴ There is now wide agreement in most fields that we are at a very exciting time in the history of science as cyberinfrastructure converges with the increased demand for meeting grand challenges through multiscale, multimodal, multisite science.

Of particular relevance to the OER movement are major disciplinary “collaboratories” (instances of a virtual organization) which are becoming functionally complete: through web portals, members of the collaboratory can reach all the colleagues, computational models, data and literature, and instrumentation they need to do their work. As illustrated in Figure 8, the cyberinfrastructure platform relaxes constraints of time and distance (geographic, disciplinary, and institutional distance) enabling people, information, and facilities to be linked and used in all four quadrants of same and different time and place. It can dramatically scale up access and participation. Physical proximity (same time and same place) continues to be important, but is now richly augmented by collaborative work flowing through all four variants of time and place. Similar shared knowledge environments by different names are being created as part of the NSF TeraGrid Project.¹⁴⁵ In this case the collaboratories are called “science gateways” (the gateways *into* collaboratories). Many of these science gateways are being designed to support both research as well as authentic, participation-based learning at K–12, undergraduate, and graduate levels. The TeraGrid website provides descriptions of about 25 such science gateways.¹⁴⁶ The Nanohub¹⁴⁷ science gateway is a particularly strong example of a site designed to support both frontier research and complementary authentic learning—a dual-use collaboratory. The science gateways provide access not only to open content but also to open scientific instruments and mentored, authentic experience in a community of practice.

Perhaps even more in the spirit of the OER culture is the Open Science Grid¹⁴⁸ (OSG), a globally distributed computing infrastructure for large-scale scientific research, built and operated by a consortium of universities, national laboratories, scientific collaborations, and software developers. There is also a growing participatory learning component to the OSG. For example, OSG is collaborating with the NSF’s Interactions in Understanding the Universe

¹⁴⁴ <http://www.nsf.gov/oci/>

¹⁴⁵ <http://www.teragrid.org/>

¹⁴⁶ http://www.teragrid.org/programs/sci_gateways/

¹⁴⁷ <http://www.nanohub.org/>

¹⁴⁸ <http://www.opensciencegrid.org/>

(I2U2)¹⁴⁹ project supporting e-Labs based on Grid middleware, as well with the TeraGrid in its education and training activities. The Mariachi experiment¹⁵⁰ to detect extreme energy cosmic rays (EECRs) is also a member of OSG and participates in education and outreach activities.

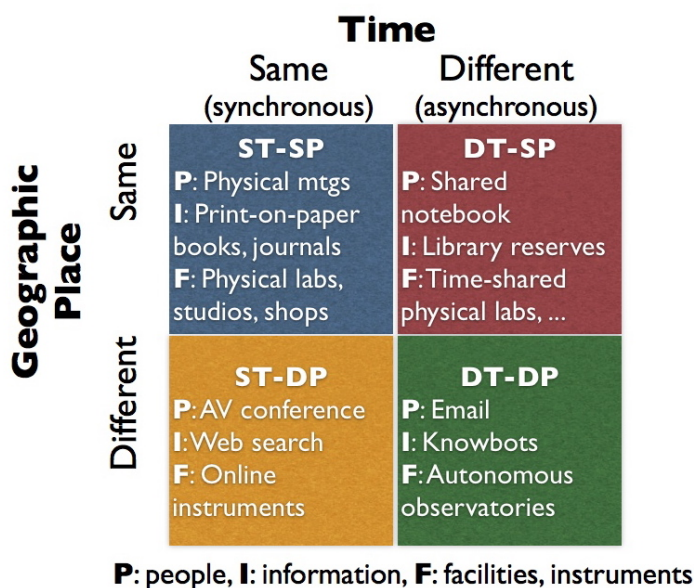


Figure 8—Virtual organizations offer additional modes of interaction between people, information, and facilities

There is enormous opportunity for synergy and mutual benefit between the international e-science/CI movement and the international OER movement, particularly in evolving to the next phase: an open participatory learning infrastructure in service of learning and discovery.

3.3.2 Cyberinfrastructure-Enhanced Humanities

Science and engineering communities have led the creation and application of computer and communication technology. They pilot advanced use that then becomes the norm. The humanities, on the other hand, have often been stereotyped as information technological laggards or even anti-technologist. It is therefore particularly noteworthy that there is a growing interest in the strategic implications of cyberinfrastructure for the humanities and a companion interdisciplinary community pursuing specific projects in this area.

The American Council of Learned Societies¹⁵¹ (ACLS) is a private, nonprofit federation of sixty-eight national scholarly organizations whose mission is “the

¹⁴⁹ <http://ed.fnal.gov/uueo/i2u2.html>

¹⁵⁰ micray.bnl.gov/

¹⁵¹ <http://www.acls.org/>

advancement of humanistic studies in all fields of learning in the humanities and the social sciences and the maintenance and strengthening of relations among the national societies devoted to such studies.” In December of 2006, the ACLS released a report on a two-year study by the Commission on Cyberinfrastructure in the Humanities and Social Sciences, supported by the Mellon Foundation. The Commission carried out research, hearings, and consultations to gather information and develop perspective in 2004. A draft report was issued in 2005 for public comment, the intended audience including the scholarly community and the societies that represent it, university provosts, federal funding agencies (including but not limited to the NSF), and private foundations.

The final report, *Our Cultural Commonwealth*, is now available from the ACLS website.¹⁵²

This report should be required reading for those going forward with investments in the OER movement and we cannot do it justice in this brief summary. We will, however, list the primary recommendations, which include subtext addressed to different constituencies: funders, universities, technology providers, cultural institutions, etc. We assume that the connection between these recommendations and the future of the OER movement is fairly obvious. The top-level recommendations are as follows:



1. Invest in cyberinfrastructure for the humanities and social sciences as a matter of strategic priority.
2. Develop public and institutional policies **that foster openness and access.**¹⁵³
3. Promote cooperation between the public and private sectors.
4. Cultivate leadership in support of cyberinfrastructure from within the humanities and social sciences.
5. Encourage digital scholarship.
6. Establish national centers to support scholarship that contributes to and exploits cyberinfrastructure.

¹⁵² <http://www.acls.org/cyberinfrastructure/cyber.htm>

¹⁵³ **Emphasis** by the writers of this report.

7. Develop and maintain open standards and robust tools.
8. Create extensive and reusable digital collections.

Finally, the Commission calls for specific investments, not just of money but also of leadership, from scholars and scholarly societies; librarians, archivists, and curators; university provosts and university presses; the commercial sector; government; and private foundations.

The U.S.-based group we know of that is the most active on some of these recommendations is HASTAC (pronounced “haystack”), which stands for the seldom-used Humanities, Arts, Science and Technology Advanced Collaboratory.¹⁵⁴ It is a growing consortium of humanists, artists, scientists, social scientists, and engineers from universities and other civic institutions across the United States, and increasingly internationally, who are committed to new forms of collaboration through the creative use of technology. Since 2003 the HASTAC community has been developing tools for multimedia archiving and social interaction, gaming environments for teaching, innovative educational programs in information science, virtual museums, and other digital projects. Its stated state aim is “to promote expansive models for thinking, teaching, and research.” During the 2006–2007 academic year HASTAC is organizing impressive public lectures on various campuses. This “InFormation” activity will conclude with the first HASTAC International¹⁵⁵ Conference in April 2007.¹⁵⁶

There are many other activities, likely already on the Hewlett radar, focused on building high-quality open content for the humanities and popular culture. These include, of course, the Library of Congress American Memory¹⁵⁷ and multilingual Global Gateway¹⁵⁸ projects and more recently the National Archives.¹⁵⁹ The pilot project at the Archives goes well beyond scans of historical documents, including, for example 3-D renderings of historic government ships reconstructed from the official blueprint drawings. Surely many similar activities are under way outside the United States that can be founded and pursued as resources to serve the international, cross-cultural objectives of OER.

¹⁵⁴ <http://www.hastac.org/>

¹⁵⁵ Including we understand, some developing countries.

¹⁵⁶ <http://www.gridtoday.com/grid/1134833.html>

¹⁵⁷ <http://memory.loc.gov/ammem/index.html>

¹⁵⁸ <http://international.loc.gov/intldl/intldlhome.html>

¹⁵⁹ <http://www.archives.gov/era/index.html>

3.4 Concluding Remarks

We hope that the brief treatment is taken as evidence that there is a huge opportunity for cooperation between several threads of initiatives with somewhat different but overlapping goals, enabled by and dependent on essentially the same underlying (cyber) infrastructure. We feel strongly that the conditions for a perfect storm on innovation exist, and we are encouraging the Hewlett Foundation to lead in triggering that storm. In the next section we provide more details about what we recommend Hewlett do.

4 The Next Phase: Open Participatory Learning Infrastructure (OPLI) Initiative

4.1 Introduction

We are recommending that the Hewlett Foundation continue to nurture global open educational resources, but to do so on a larger and more diverse scale and in the context of an even bolder goal—to shape a new culture of learning that is now possible in the digital world. We believe that the Hewlett Foundation can play a leadership role in weaving the threads of an expanded OER movement; the e-science movement; the e-humanities movement; new forms of participation around Web 2.0; social software; virtualization; and multimode, multimedia documents into a transformative open participatory learning infrastructure—the platform for a culture of learning.

We are not recommending a direct assault on institutionalized higher education but rather establishing new alternatives to learning for more people in the world. Bold change at the edges of the formal education system, at all levels, will eventually propagate into and change the core.

Hewlett will have the greatest impact on education by catalyzing¹⁶⁰ an infrastructure that will be supported and used by many for open participatory learning. Infrastructure and creating infrastructure are often taken for granted, but understanding infrastructure—the dynamics, the tensions and the design—is a rich and interesting topic, and infrastructure is often the most complex and expensive undertaking of a society.

4.2 Understanding Infrastructure

A recent report from a workshop, *Understanding Infrastructure: Dynamics, Tensions, and Design*,¹⁶¹ along with the community producing it, are relevant to the OPLI Initiative. We will touch on the highlights most relevant to understanding the *what* and *how* of the OPLI initiative. We encourage, however, careful study of the full report and possible consultation with some of the authors. Relevant work from economists¹⁶² on concepts such as *the case for commons* and *pooling arrangements* can be used to inform the OPLI initiative as can typologies of infrastructure organized on *commercial, government, and social*

¹⁶⁰ Although it has not been characterized as an infrastructure initiative, much of the OER initiative is about evolving infrastructure for enhanced creation and use of infrastructure for accessing digital content.

¹⁶¹ <http://www.si.umich.edu/InfrastructureWorkshop/>

¹⁶² For example, *Role of intellectual property in constructing/designing open environments through pooling arrangements*, Brett Frischmann, <http://numenor.lib.uic.edu/fmconference/viewabstract.php?id=12>

stakeholders. This community might help assure that the OER and OPLI initiatives produce *positive externalities and large social surplus*.

Since the 1980s, historians, sociologists, economists, and information scientists have been studying how and why infrastructures form and evolve; how they work; and how they sometimes disintegrate or fail. This work reveals some base-level tensions that complicate infrastructural development and challenge simple notions of building infrastructure as a planned, orderly, and mechanical act. These tensions and examples of them include

- Time—short-term funding decisions vs. the longer time scales over which infrastructures typically grow and take hold;
- Scale—disconnects between global interoperability and local optimization; and
- Agency—navigating processes of planned vs. emergent change in complex and multiple-determined systems.

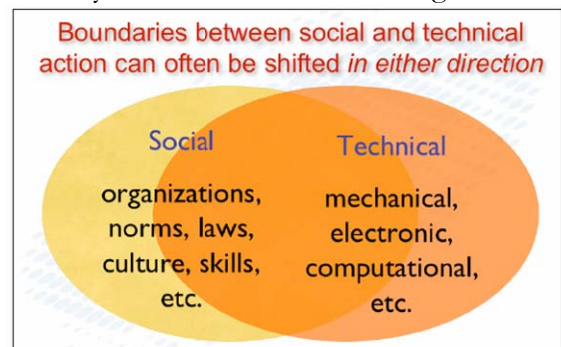
Important concepts and points made by this workshop, **and adopted extensively from their report**, include the following:

4.2.1 Fostered, Not Built

Infrastructure is not built from a blueprint, nor necessarily a centralized government-dominated activity. Cyberinfrastructure, especially, emerges from highly distributed, complex, multi-actor processes informed by heuristics for linking isolated and local systems. Although “systems” are technically recursive (a system is a system of systems), it is useful to distinguish **infrastructure** as resulting from establishing interoperability between otherwise heterogeneous local and specialized systems. (For example transformers, inverters, and mechanical plug-adapters enable a global electricity infrastructure.)

The complications of time, scale, and agency challenge simple notions of infrastructure building as a planned, orderly, and mechanical act. They also

suggest that boundaries between technical and social solutions are mobile, in both directions: the path between the technological and the social is not static and there is no one correct mapping. Robust cyberinfrastructure will develop only when social, organizational, and cultural issues are resolved in tandem with creating technology-based services. Attention to these concerns will be critical to long-term success.



4.2.2 Dynamics

Historical infrastructures—the automobile, gasoline, and roadway system; electrical grids; railways; telephony; and most recently the Internet—become ubiquitous, accessible, reliable, and transparent as they mature. The initial stage in infrastructure formation is system-building, characterized by the deliberate design of technology-based services. Next, technology transfer across domains and locations results in variations on the original design, as well as the emergence of competing systems.

Infrastructures typically form only when these various systems merge, in a process of consolidation characterized by gateways that allow dissimilar systems to be linked into networks. In this phase, standardization and inter-organizational communication techniques are critical. As multiple systems assemble into networks, and networks into webs or “internetworks,” early choices constrain the options available, creating what historical economists call “path dependence.”

4.2.3 Tensions

Transparent, reliable infrastructural services create vast benefits, but there are always losers and winners in infrastructure formation. Questions of ownership, management, control, and access are always present. For example:

- Who decides on rules and conventions for sharing, storing, and preserving resources?
- Local variation vs. global standards: how do we resolve frictions between localized routines and cultures that stand in the way of effective interoperability and collaboration?
- How can national cyberinfrastructure development move forward without compromising possibilities for international or even global infrastructure formation?

4.2.4 Design

These and other tensions inherent to infrastructure growth present imperatives to develop navigation strategies that recognize the likelihood of unforeseen (and potentially negative) path dependence and/or institutional or cultural barriers. The proposed OPLI seeks to enable a decentralized learning environment that: (1) permits distributed participatory learning; (2) provides incentives for participation (provisioning of open resources, creating specific learning environments, evaluation) at all levels; and (3) encourages cross-boundary and cross cultural learning.

Because all three of these goals are simultaneously social and organizational in nature and central to the technical base, designing effective navigation strategies

will depend on collaboration between many different individuals and organizations: resource providers, resource aggregators, technology and learning researchers, and technology providers, etc. Representatives of many of these activities already exist in the OER community catalyzed by the Hewlett OER initiative. Furthermore Hewlett already understands some of the waters through which it must navigate toward an open participatory learning infrastructure.

4.2.5 The Long Now of Infrastructure

Accustomed as we are to the information revolution, the accelerating pace of the 24/7 lifestyle, and the multi-connectivity provided by the World Wide Web, we rarely step back and ask what changes have been occurring in the background, at a slower pace. For the development of cyberinfrastructure (or a particular flavor of cyberinfrastructure that we are calling the OPLI), the long now is about 200 years. This is when two suites of changes began to occur in the organization of knowledge and the academy that have accompanied—slowly—the rise of an information infrastructure to support them: an exponential increase in information gathering activities by the state (statistics) and knowledge workers (the encyclopedists), and the accompanying development practices to sort, sift, and store information.

This long-now perspective invites a discussion of first principles. For this we return to Star and Ruhleder's¹⁶³ now-classic definition of infrastructure, originally composed for a paper on one of the early scientific collaboratories, the Worm Community System. They show how their definitions can be ordered along two axes: the social/technical and the local/global.

¹⁶³ Star, S. L. and K. Ruhleder (1996). "Steps toward an ecology of infrastructure: Design and access for large information spaces." *Information Systems Research* 7(1): 111-134.

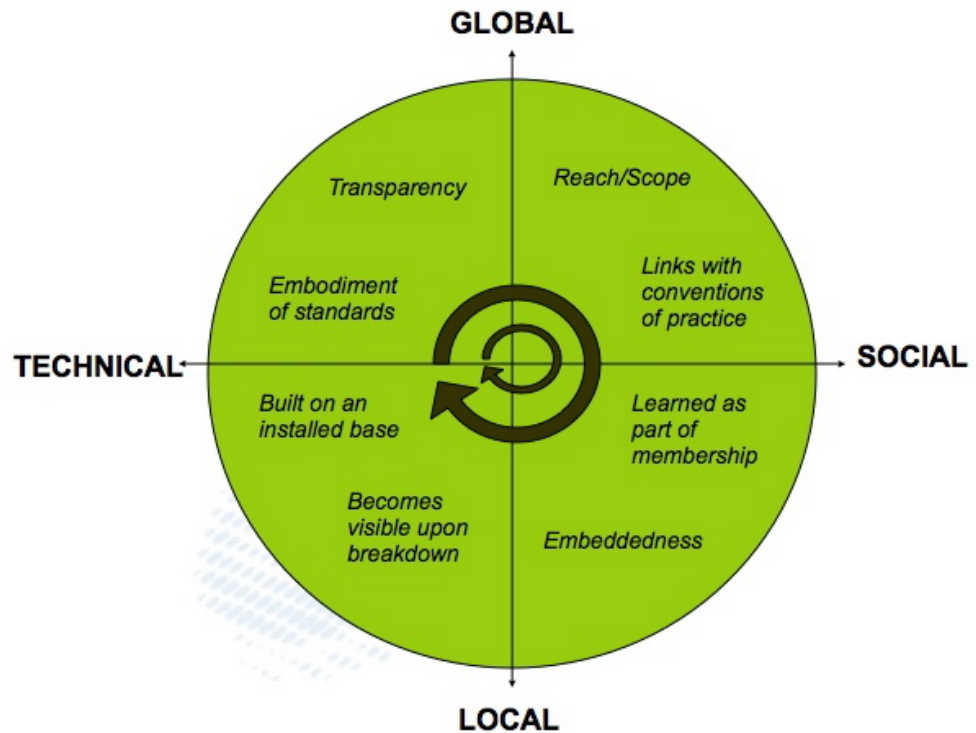


Figure 9—Boundaries between social and technical work can be shifted in either direction.

According to their model in creating the OPLI, the key question is not whether this is a “social” problem or a “technical” one. The question is whether we choose, for any given problem, a social or a technical solution—or some combination. It is the distribution of solutions that is the object of study. An everyday example comes from the problem of e-mail security. How do I distribute my trust? I can delegate it to my machine and use pretty good encryption for all my e-mail messages. Or I can work socially and organizationally to make certain that sysops, the government, and others who might have access to my e-mail internalize a value of my right to privacy. Or I can change my own beliefs about the need for privacy—arguably a necessity with the new infrastructure. A thorough discussion of the Star and Ruhleder model is beyond the scope of this report. The key points here are:

1. perhaps without thinking about it in these terms, Hewlett has in fact been nurturing the creation of infrastructure in the OER initiative; and
2. there is a substantial body of literature, experience, and academic expertise that could assist in creating a principled approach to the OPLI initiative.

For our purposes, the OPLI is the set of **organizational practices**, **technical infrastructure**, and **social norms** that collectively provide for the smooth operation of high-quality open learning in distributed, distance-independent ways. All three are objects of design and engineering; the creation of a successful infrastructure will fail if any one is ignored.

Other excellent resources for informing the design of the OPLI initiative are the papers, presentations, and diverse community of experts who came together at the National Academies Washington in January for two days of shared learning at the Designing Cyberinfrastructure for Collaboration and Innovation conference. The website¹⁶⁴ includes a large number of relevant resources already and will be augmented as the final papers are available. The talks that were mostly highly relevant to an OPLI, were:

- Infrastructure for Knowledge and Innovation
- Designing the Virtual Organization
- Technology-Enabled Knowledge
- The Ecology and Design of “Open”
- Between Public and Private: Bridges, Fences, and New Terrain
- Pooling and Integration
- Architecting the Knowledge Commons
- Standards Development under Pressure
- Aligning Patents and Knowledge

4.3 Learning Enabled by an Open Participatory Learning Infrastructure (OPLI)

So what is the Open Participatory Learning Infrastructure that we are promoting as a platform on which the world can build what we have called learning ecosystems or cultures of learning? The ecosystem analogy may be the most vivid. In science an ecosystem is defined as a dynamic system in which living organisms interact with one another and with their environment. These interactions can be very complex and take many forms. Organisms prey on one another; compete for nutrients; have parasitic or symbiotic relationships; wax and wane; prosper and decline. And an ecosystem is never static; it’s in a state of perpetual ferment. Learning on an OPLI platform should similarly always be in a state of perpetual ferment.

¹⁶⁴ <http://cyberinfrastructure.us/>

At this point we can only suggest some of the attributes of the OPLI and the models of learning it will support. Part of the challenge for Hewlett will be establishing the sensemaking and iterative design that will define and realize the OPLI—the participants will be crossing the bridge as they are building it. At least three types of activity must be brought into a synergistic relationship: (1) creating and provision infrastructure; (2) meaningful and transformative use of the infrastructure; and (3) discovery and transfer of the fruits of relevant research into future generations of the infrastructure.

We will attempt a preliminary sketch of what we have in mind. Let's start by mapping out a dream space for participatory learning that enables students anywhere to engage in experimenting, exploring, building, tinkering and reflecting in a way that makes learning by doing and productive inquiry a seamless process.

According to several websites^{165 166} there are about 8,000 universities worldwide. There are many other institutions of higher learning, including training centers and community centers. In addition there are tens of thousands of institutions that support “informal” learning—libraries, museums, archives, etc. Each of these centers of learning are themselves practicums but are they reflective practicums? Are they evaluating what they do and engaging in anything resembling cycles of continuous improvement? Are their reflections being captured and shared? Somehow we need to construct a shared, distributed, reflective practicum—where experiences are being collected, vetted, clustered, commented on, tried out in new contexts, and so on.

One might call this learning about learning, a bootstrapping operation—all made possible by an OPLI—where the teachers and administrators are learning among and between themselves. We want to create a space where the teacher as entrepreneur—whether a certified schoolteacher, a home schooling parent, a librarian, a community center leader, or a retired professional can share and learn—share material, exercises for students, experiments, projects, portfolios of examples, etc.

The imagination starts to run wild when one thinks about a new kind of simulation and visualization—highly instrumented courseware all living in a spiral of continual improvement through use, augmentation and remix because of Web 2.0 techniques. This becomes a living or dynamic infrastructure—itsself a reflective practicum.

¹⁶⁵ <http://www.braintrack.com/>

¹⁶⁶ <http://univ.cc/>

4.3.1 Peer Learning and Labs on the Wire

Toward creating a culture of activity-based, participatory learning (including significant peer learning) we might start by considering the role of the Faulkes Telescope Project¹⁶⁷ in Australia or the Bugscope project¹⁶⁸ in the United States. The Faulkes Telescope Project provides access to a global network of robotic, online telescopes for research-based science education. The Bugscope project is an educational outreach program for K–12 classrooms. The project provides a resource to classrooms so that they may remotely operate a scanning electron microscope to image “bugs” at high magnification. The microscope is remotely controlled in real time from a classroom computer over the Internet using a Web browser. Students also have access to faculty expertise to answer questions as they arise in the observations.

Given today’s cyberinfrastructure, why haven’t we blown open the ability to give students anywhere access to serious scientific instruments—instruments to explore nature’s secrets as an adventure? Imagine the MIT iLabs Project¹⁶⁹ done large scale and complemented by access to capabilities like the MOSIS¹⁷⁰ integrated circuit fabrication server. This could provide open access to both building and evaluating complex circuits. Now consider the Fab Labs¹⁷¹ project at MIT. MIT’s Fab Labs project aims to give ordinary people around the world the technology to design and make their own stuff. Is this the dawn of the age of personal fabrication? It is used by humanists, architects, and engineers to learn how to build almost anything and learn how to use sophisticated equipment to assist in building.

Along the same lines, particularly if more focused toward participatory learning, is the Fab@Home¹⁷² Project. Here is an overview from the Web:

¹⁶⁷ <http://faulkes-telescope.com/>

¹⁶⁸ <http://bugscope.beckman.uiuc.edu/>

¹⁶⁹ <http://icampus.mit.edu/ilabs/>

¹⁷⁰ <http://www.mosis.org/>

¹⁷¹ http://www.boston.com/news/globe/ideas/articles/2005/01/30/how_to_make_almost_anything/

¹⁷² [http://www.fabathome.org/wiki/index.php?title=Fab percent40Home:Overview](http://www.fabathome.org/wiki/index.php?title=Fab+percent40Home:Overview)

Universal manufacturing embodied as today's freeform fabrication systems has – like universal computers – the potential to transform human society to a degree that few creations ever have. The ability to directly fabricate functional custom objects could transform the way we design, make, deliver and consume products. But not less importantly, rapid prototyping technology has the potential to redefine the designer. By eliminating many of the barriers of resource and skill that currently prevent ordinary inventors from realizing their own ideas, fabbers can “democratize innovation.”¹⁷³ ¹⁷⁴

¹⁷⁵

Ubiquitous automated manufacturing can thus open the door to a new class of independent designers, a marketplace of printable blueprints, and a new economy of custom products.

Fabbers (a.k.a 3D Printers or rapid prototyping machines) are a relatively new form of manufacturing that builds 3D objects by carefully depositing materials drop by drop, layer by layer. Slowly but surely, with the right set of materials and a geometric blueprint, you can fabricate complex objects that would normally take special resources, tools and skills if produced using conventional manufacturing techniques. A fabber can allow you explore new designs, email physical objects to other fabber owners, and most importantly - set your ideas free. Just like MP3s, iPods and the Internet have freed musical talent, we hope that blueprints and fabbers will **democratize innovation.**

Creating a culture of learning will end up redefining how we think about work, leisure, and entertainment.

4.3.2 Exploiting Specialized Resources

Such participatory learning environments return us to a land of passionate building and tinkering—getting a feel by doing. OPLI can be a platform for extending to developing countries some of the learning innovation in engineering education at Olin College,¹⁷⁶ a new school with little institutional

¹⁷³ Burns M., (1995) The Freedom to Create, in Technology Management, Volume 1, Number 4 <http://www.ennex.com/~fabbers/publish/199407-MB-FreedomCreate.asp>

¹⁷⁴ Gershenfeld N., (2005) FAB: The Coming Revolution on Your Desktop – From Personal Computers to Personal Fabrication, Basic Books <http://cba.mit.edu/projects/fablab/>

¹⁷⁵ Lipson H. (2005) “Homemade: The future of Functional Rapid Prototyping”, IEEE Spectrum, feature article, May 2005, pp. 24-31

http://www.mae.cornell.edu/ccsl/papers/Spectrum05_Lipson.pdf

¹⁷⁶ http://en.wikipedia.org/wiki/Franklin_W._Olin_College_of_Engineering

inertia to overcome when adopting new practices. It attempts to set itself apart from traditional engineering schools through its focus on project-based and team-based learning, its interdisciplinary approach, and its unique organizational structure.

Universities and other centers of knowledge worldwide have been creating special collections, websites (often associated virtual communities of practice) around narrow topics, for example Decameron Web,¹⁷⁷ The Valley of Shadow,¹⁷⁸ The Perseus Project,¹⁷⁹ websites on the Civil War, and on and on. These become rich sites to explore and even participate in—starting to engage in *learning to be* a scholar. There are likely now hundreds of such high-quality sites with many in the humanities. Consider the MIT Shakespeare Ensemble and the ability it offers to pull up different (video and movie) performances of Hamlet and see/feel the wide range of interpretations different directors have given. Which one seems right and why?

Returning to history, how might one get youth to take some of this material and build games around them? This is a rich tapestry of history games already, but how do they get used in history classes, if they do at all? What kinds of discussions can they foster?

Moving back to engineering and science, recall the critically acclaimed series at Cal Tech called *The Mechanical Universe...and Beyond*.¹⁸⁰ This is a series of fifty-two thirty-minute videotape programs covering the basic topics of an introductory university physics course. It includes hundreds of spectacular computer animation segments created by the famed graphics guru, Jim Blinn. The National Science Foundation later funded production of a seven-hour high school adaptation suitable for high school physics students, and it has been translated into nine languages. But this just scratches the surface of what could be done to get people of any age to understand how the mechanical universe works. How could high-quality resources such as these be remixed and reused in even more powerful ways? We have already alluded to the vast capabilities of visual simulations—but there is now little way to know what each other is doing, what has worked, what can be shared and so on. Could a pervasive OPLI reduce this lost-opportunity cost?

Consider Andy van Dam's ambitious proposal to build, in a distributed and federated way, a clip library of simulations¹⁸¹ (sim clips) that recursively delve deeper into a topic. His focus initially was the human body, which can be viewed at multi-scale (both spatial and temporal) levels, but at each level each

¹⁷⁷ http://www.brown.edu/Departments/Italian_Studies/dweb/dweb.shtml

¹⁷⁸ <http://valley.vcdh.virginia.edu/>

¹⁷⁹ <http://www.perseus.tufts.edu/>

¹⁸⁰ <http://www.its.caltech.edu/~tmu/>

¹⁸¹ <http://www.educause.edu/apps/er/erm05/erm0521.asp>

sim clip can be rendered visual and tinkered with in and out of context. Building a multi-scale complete simulation of the human body is enough of a challenge, let alone finding an architecture that is flexible enough to allow thousands of people to contribute in ways that compose and recurse.

Such a simulation would be of use to learners of all ages and again could yield an infinite number of grounded conversations—not just random blogs talking to each other, but rather create a context in which you run a simulation to prove your point. Now the contested ground becomes the quality and validity of the simulation and the interpretation of its results. The twenty-first century is a century of biology, yet we are creating the visualization tools, the simulations, and workflow environments to get a feeling for this domain. The simple magic of the cell as machine and how that machine works is awesome. For some of us, the movie “The Fantastic Voyage” had images and drama in it that still years later are cemented in our mind. Think about creating machinima movies¹⁸² based on experiments or simulations composed from the sim clip library. This raises the question of whether NSF and NIH will expect most anything they fund to eventually be folded into a simulation of the subject. All the above suggests that we are shifting from static content to increasingly active content that is hopefully more and more systemically integrated.

4.3.3 Content + Context

Content was king, and open content we hope will be even more royal, but perhaps today the ruler is content + context. In the digital era we can start considering many different contexts in which learning will transpire. The learning-on-demand scenario has already transformed the need to spend all one’s time memorizing facts. Google becomes a living index and repository for enormous content. We now live in a world of abundance where editing and curating become more crucial than ever.

It is under-appreciated how Google has empowered the geek generation to be fearless in picking up new languages, etc. Why? Because language compilers, integrated debugging environments, and operating systems generate error codes when they get stuck. An error code is meaningless to a human but it does wonders as input to Google. Just type it in (plus the system you are using) and instantly Google gives you pages and pages of fellow geeks who have encountered that same error code along with what it means and what to do about it. This has allowed, for example, a 60-year-old colleague to run a one-person software shop to confidentially master Java and Enterprise JavaBean (EJB). He was not going to go back to school; he accepted a task to build a system in EJB using Google as a primary (open) resource.

¹⁸² Making movies in virtual reality. See <http://www.machinima.com/>

Might we build and host in an OPLI a vast video library of master teachers that could be indexed, commented on and parsed? MIT's new browser shows promise for automatic speech recognition; it is trained only by giving the system some papers written by the lecturer. Once transcripts are created, we are able to access just that part of a lecture to get a quick refresher or memory jog. Or a teacher might use it to slip something into his or her own lecture. Universities focus on both timeless issues and very timely issues. We need to find ways to capture more of the latter so one starts to think of OPLI-based services as a place to come or an infrastructure to use to find out about the latest developments in a particular field. This is in part what we discussed earlier about increasing the granularity of what can be accessed and reused within a resource collection.

An emphasis throughout this report is how can we create material that can be radically repurposed and remixed where appropriate. Key to making the whole more than the sum of the parts is to create some XML¹⁸³ schemes with at least a minimal amount of markup capability. How detailed it should be or how it evolves is an open question. Currently, one could argue not only is the whole not more than the sum of the parts; it is more often closer to the *difference* of the parts—more does not necessarily mean better; in fact, it often overloads us. We need new powerful assists from the merger of social filtering, search, and visual browsing schemes to survive. We also need social software and social sites for critiquing and sharing experience: sharing material + sharing experience = closing loops to make resources better. Some of these resources are very transient, but much of what is done gets repurposed decades later. We need to solve the archival problem in OPLI (others will) but we must recognize that archiving of multimedia material is a problem in itself.

4.4 Some Functional Attributes of an OPLI

Having sketched some of the gestalt of learning in the OPLI-enabled work, we will now list some of the necessary attributes of the underlying OPLS.

- **Extensible**—we are in a turbulent embryonic stage although middleware projects like Globus¹⁸⁴ are making headway. Google and YouTube are not solutions or even initial platforms, but they will evoke and provoke our imaginations.
- **Remixable**—discussed earlier.
- **Repurposable**—automatic scaling and transcoding between wall-size screens and mobile PDAs.

¹⁸³ extended markup language.

¹⁸⁴ <http://www.globus.org/>

- **Service-oriented**—a contemporary architectural form for distributed systems.
- **Multi-lingual**—required for global reach and impact. Translation services are part of OPLI.
- **Incremental and architecturally light at its roots**—as http was initially.
- **Interchange on demand**—Use powerful but cheap computation power to convert between standards and systems rather than struggle for universal agreement on standards. More generally we may now be on the verge of having more computing cycles than we know what do with. So much in the past has been constrained by the assumption of scarce bandwidth and cycles that none of our institutions are prepared to think through new ways of teaching, learning, creating content, modes of sharing, instrumenting, and improving served by infinite computing power. We need to find ways to think out of the box.
- **Human-centered and socio-technical in nature**—many different kinds of audiences, needs, capabilities, and lack of understanding. Avoid the pitfall of viewing OPLI as primarily a technical set of issues. Charles Vest, former President of MIT, probably receives the credit he deserves for finding a way to bring the faculty into OCW. OCW is a major institutional innovation, not a technical one. There will be the need for many more such institutional innovations.
- **Support a spectrum of openness**—Openness is a characteristic based on accessibility and responsiveness.¹⁸⁵
 - Most products, services, or processes are neither open nor closed, but can be placed on a continuum of openness.
 - Moving toward openness means increasing accessibility and responsiveness.
 - The degree of openness required depends on the purpose of the activity and the need to exercise judgment and control.
- **Support for collaborative learning in multi-role, hybrid groups**—Peer learning can only go so far. We need ways to enable hybrid learning contexts: a mixture of peers with mentors, coaches, and guides.

¹⁸⁵ Based on presentation and personal communication with Elliot Maxwell, emaxwell@emaxwell.net.

- **Highly and smartly instrumented**—learning in OPLI is computer mediated, especially the distributed part, and we must instrument what goes on to get some really fine-grain analysis of what is working and why. More generally, a key opportunity is to figure out how to make learning experiments more powerful and relevant to more people. The openness of the systems and the artifacts and resources in it should contribute to finer-grained, more nuanced assessment.

4.5 Some Thoughts about How

We doubt that this will be a business-as-usual undertaking for the Education Program at the Hewlett Foundation. Careful thought will need to go into the meta question of how to mount this initiative. Here are some of our suggestions:

1. Identify and engage representatives from the community of OPLI funders and performers in a series of workshops to build common vision of the opportunity space and to find specific roles for them. Use a combination of face-to-face and online meetings. (We can help identify candidate participants.) This can be supplemented by a series of private meetings with possible funding partners.
2. Use input from these workshops, this report, and other retrospectives of the OER to establish a vision document (similar to what NSF did for the cyberscience activities mentioned in Section 3).
3. Within the general framework of this vision document develop a set of funding opportunities through: invitation, a venture fund for relatively small unsolicited proposals, and one or more solicitations for major funding. The solicitations could be an open invitations (perhaps worldwide) but multiphase: letter of intent, pre-proposal, full proposal. Proposers could be eliminated at any of these stages. Hewlett could consider outsourcing management of the review process to other places. The NSF, for example, often provides this service to other federal agencies and may be able to do so for private foundations.
4. Establish a standing external advisory committee and a cadre of on-call consultants.
5. Ramp up program officer staffing inside Hewlett, select and fund a project coordination office at a university or other nonprofit institution., or do both. The project office would handle much of the day-to-day coordination of the OPLI grantee community. Consider models such the relationship between NSF and the National Center for Atmospheric

Research (NCAR). NCAR is an example of a federally funded research and development center. The OPLI initiative could be conducted primarily through a Hewlett (and others?) funder R&D center.

6. Although we have been using the words *grant* and *grantee* we suggest that much of this program would be funded as what NSF calls a “cooperative agreement.” A cooperative agreement is an arrangement somewhere between a contract with clear deliverables, and a grant with no specific expectations nor much oversight from the funder. More generally, there could be funding models and experience at the NSF that might be appropriated by Hewlett.
7. As Hewlett has done in OER, build a community that will interact and increasingly build common ground on the vision, approach, and opportunities for collaboration. Promote humble listening and collective action between normally competitive communities.

4.6 Why Hewlett and Why Now?

We have been looking over Hewlett’s shoulder at the OER movement now for several years and have grown increasingly enthusiastic, respectful, and excited about what the Foundation’s investments of money and leadership have accomplished.¹⁸⁶ The Hewlett Foundation is the recognized leader in nurturing the OER movement, and in our judgment is almost the only place to catalyze, in partnership with other private and government foundations, the next logical step from open resources to open participatory learning. Hewlett has the global network of grantees, the global reach to many others, the momentum, the entry to most any person or institutions worldwide, the flexibility, the agility, and the personal commitment of program officers. It has shown that it can attract the best to work with in this emerging field.

The primary goal of Section 3 was to address the *why now* question. The world is fortunate to have several major cyberinfrastructure-based, revolutionary movements under way that could now be linked for extraordinarily positive social benefit. The good news is that these are largely community-driven initiatives with a life of their own. The bad news is that without some conceptual and financial “force fields” from enlightened funders, these communities may go their separate ways with suboptimal or even balkanized outcomes. There is now an open window of time in which to act.

¹⁸⁶ Our enthusiasm is manifest in the fact that we have very willingly worked on this review and report at a level well beyond what we initially thought we had signed up for.

Bold initiatives for change such as OER and OPLI are not easy, but this, as Machiavelli¹⁸⁷ reminds us, is nothing new.

It must be considered that there is nothing more difficult to carry out, nor more doubtful of success, nor more dangerous to handle than to initiate a new order of things; for the reformer has enemies in all those who profit by the old order and only lukewarm defenders in all those who would profit by the new order; this lukewarmness arising from the incredulity of mankind who does not truly believe in anything new until they actually have experience of it.

¹⁸⁷ Niccolo Machiavelli, *The Prince*, translated by Daniel Donno (Bantam Classics: New York, 1986)

5 Appendix: The Realities of Information and Communication Technology in Developing Region and Implications for OER Initiatives

This Appendix will look at present information and communication technologies (ICT) in developing regions; new technologies and trends that could be important within five years; case studies that illuminate those trends; and venues and emerging opportunities that may be ripe for testing. The educational context for this discussion is equally important, but will not be documented in detail. It can be summarized by saying that in many developing countries, and especially in rural areas, public education systems are of poor quality, they frequently lack textbooks and other materials, and educational strategies often tend toward rote learning. Thus the potential of open source educational materials along with digitally based, multimedia, and interactive educational approaches to significantly improve educational opportunities—indeed, to leapfrog them from very poor to world class—is very high. Consider, too, the apparent fact that youth in developing regions find digital technology at least as appealing as do youth in developed areas. Against that potential must be set the realities of ICT and electrical infrastructures as well as policy regimes that strongly influence and constrain those infrastructures in developing countries.

5.1 The Reality of ICT Infrastructure and Connectivity in Developing Regions

This section will consider mobile phones and Internet access, for reasons that will become clearer in due course, but that can be summarized by noting the convergence of mobile phones and computers and the rapid emergence of mobile phones as the dominant ICT platform in developing countries.

The spread of wireless mobile phone networks has been especially rapid in developing regions in recent years. From a small base, the number of mobile subscribers in developing countries grew more than five-fold between 2000 and 2005 to reach nearly 1.4 billion, with rapid growth in all regions. The fastest growth was in sub-Saharan Africa, to a total of nearly 77 million. Nigeria's subscriber base grew from 370,000 to 16.8 million during those five years, while the Philippines' grew six-fold to 40 million.¹⁸⁸ Wireless subscribers in China (334 million), India (52 million), and Brazil (66 million) together now outnumber those in either the United States or the European Union.¹⁸⁹

¹⁸⁸ World Bank. (2006). *Information and Communications for Development, Global Trends and Policies*. Washington, DC. A comprehensive summary from which this chapter draws heavily.

¹⁸⁹ According to the International Telecommunications Union, there were a total of 2.137 billion mobile subscribers in 2005. Of those, 555.6 million were from India, China, and

Worldwide, wireless networks reached the 2 billion subscriber mark at the end of 2005; industry analysts expect there will be more than 3 billion subscribers by 2010, with 80 percent of the growth in developing countries.¹⁹⁰ Rapid growth is continuing: in India, for example, mobile companies were adding about 6 million new subscribers a month at the end of 2006.

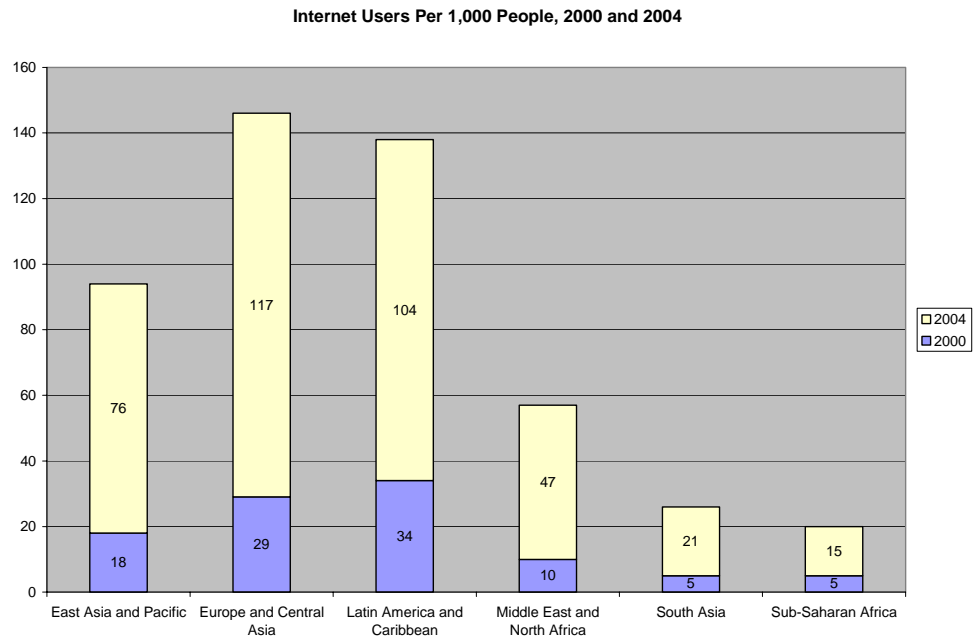
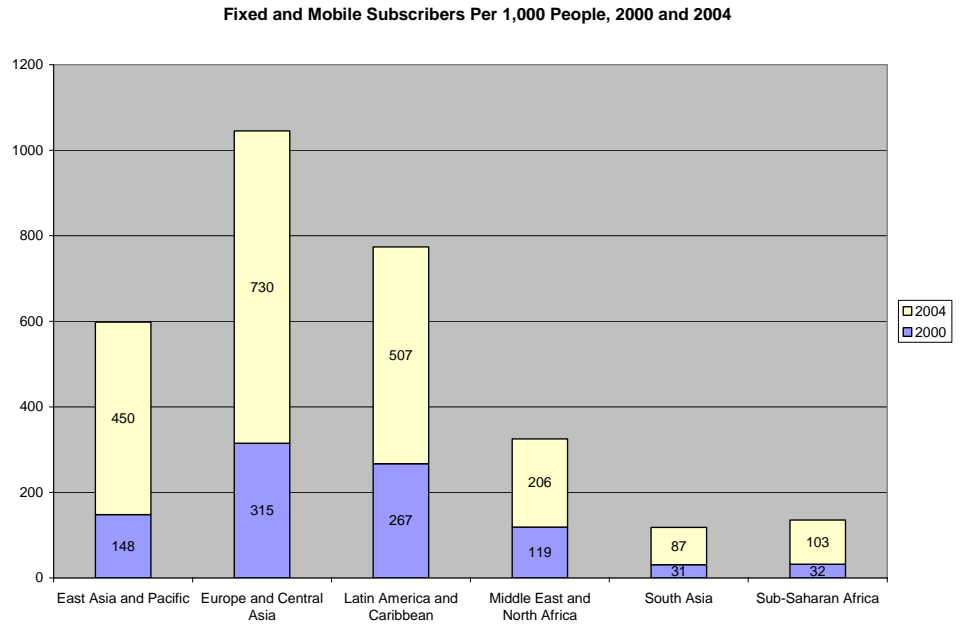
Internet access has also expanded rapidly, more than quadrupling worldwide between 2000 and 2005, with the most rapid growth in the Middle East, North Africa, and East Asia.¹⁹¹ Nonetheless, penetration is only 67 users per 1,000 people in developing countries, compared with 258 mobile users per 1,000 people, and Internet usage remains concentrated in higher-income segments and urban areas.

Still a Digital Divide. Despite rapid growth rates, these data mean that in Africa, 90 percent of the population does not have access to a phone, and 98.5 percent does not have Internet access. In South Asia, the corresponding figures are 93 and 98 percent; in the Middle East and North Africa, 79.5 and 95 percent; in East Asia, 54 and 92.5 percent; in Latin America, 49.3 and 89.5 percent. Thus 10 percent penetration is the high-water mark for Internet access, with 2 to 5 percent more typical of Africa and South Asia. Phone access is better: roughly half the population in Latin America, nearly half in East Asia, and about a tenth of the population in Africa and South Asia has mobile phones. See Figure 5.1.

Brazil (combined), while the European Union accounted for 470.6 million. The United States counts 201.6 million subscribers. See International Telecommunications Union, Market, Economics and Finance Unit. Accessed: http://www.itu.int/ITU-D/ict/statistics/at_glance/cellular05.pdf

¹⁹⁰ *GSM World News*, (2005, September, 15). Worldwide cellular connections exceeds 2 billion. GSM World News Press Release. Retrieved July 5, 2006, from the World Wide Web: http://www.gsmworld.com/news/press_2005/press05_21.shtml

¹⁹¹ World Bank, op cit, 2006.



Source: Adapted from 2006: Information and Communications for Development, Global Trends and Policies (World Bank, Washington, DC, 2006), p.6

Figure 5.1—Mobile telephone and Internet users by region, 2000 and 2004

Compounding the lack of Internet access is lack of reliable electric power, especially in rural areas, and, in many countries, the high cost of Internet access. A quarter of the world's people lack access to electricity: 77 percent in Africa; 33 percent in Asia, 17 percent in Latin America.¹⁹² Moreover, because political mandates require power grids to supply service but provide insufficient funding or create an inability to collect revenues, electric utilities are unable to maintain the grids well or meet rapidly expanding demand. The result is frequent brownouts, voltage surges that can damage digital equipment, and often only a few hours of power per day. These conditions do not encourage use of computers unless they have battery or generator backup and voltage regulating equipment, significantly adding to the cost of a PC. An equally strong deterrent is the cost of Internet access in many countries. Such costs are highest in sub-Saharan Africa, where broadband access prices are as much as ten times that of Europe, quite high in East Asia, and lower but perhaps four times the European price in South Asia.¹⁹³ Such costs make it almost prohibitive for most households, small businesses, and schools (unless heavily subsidized by government) to pay for Internet access, and especially to pay for broadband access, so that cyber cafes and other shared-access points (most of which do not provide true broadband access) become the Internet access option of choice.

Some implications for education. The bottom line is that widely available broadband Internet access does not yet exist in developing countries, and does not exist at all in most rural areas, where over half of the population lives and a significant proportion of schools are located. The supporting electric power infrastructure is also problematic, especially in Africa and South Asia. In many countries, security concerns would require that computers in schools be kept under lock and key when not in use as they are valuable, easily stolen, and can provide significant revenue to people who are desperate. The widely touted vision of providing an inexpensive laptop for every child in such countries is just that, a vision only now coming to grips with realities.¹⁹⁴ However, the situation could change significantly in the next five years, as explained in the following section.

5.2 New Technologies and Trends

PCs adapted to and priced for developing countries are beginning to emerge. Intel is rolling out in India a \$400 “kiosk” PC that is dust-proof and comes with

¹⁹² WRI analysis, “The Next 4 Billion: Market Size and Business Strategy at the Base of the Pyramid,” forthcoming 1st quarter 2007.

¹⁹³ World Bank. *op.cit.*, p.63.

¹⁹⁴ In addition to inavailability or inaffordability of Internet access and, often, electric power for schools in developing countries, such laptops would be a valuable commodity and rapidly “lost” or stolen and sold to small businesses, an almost irresistible temptation for a poor family with unaffordable medical needs or cash to meet other emergencies.

a built-in UPS (battery back-up) and is introducing a low-priced PC in the \$300 range. Microsoft is piloting a pay-as-you-go PC in Brazil that will allow low-income households to buy a computer on time, with financing provided by third parties over a year or more and continued operation of the computer tied to on-time payments.

But the more important trends are to be found in mobile phones and in new fixed wireless broadband networks. Mobile phones are already the dominant user platform in developing countries; it is expected there will be 2.5 billion users in those regions by 2010. By that time, if current trends continue, the typical mobile phone will have the processing power of today's desktop PC. It will almost certainly have a powerful digital camera, capable of both still and video imagery, and the capability to receive and play digital video and audio files. It will likely have Bluetooth or other short-range wireless capability, such that voice and data (including video) can be transferred in real time to a separate projector, whether a pair of glasses that will display images, text, or spreadsheets in a "heads-up display" (a product already nearing commercial launch) or more conventional classroom projectors, or input from a separate wirelessly connected keyboard. It may well incorporate Wi-Fi chipsets (about \$15 now, with prices dropping) so that the resulting multimode phone can also access broadband networks directly. More powerful voice recognition and voice synthesis chips may well substitute for a keyboard or a phone keypad for many uses, making it possible to listen to and dictate e-mail or instant messages. Many financial transactions are already being sent over mobile phones, especially in developing countries. Secure biometric ID capability in phones (via thumb-print readers or via server-based voice and face recognition, both already technically feasible) would help them become e-wallets and mobile bank accounts to a greater extent, which will allow the largely un-banked low-income populations to use them. And mobile phones will almost certainly offer broadband Internet access in many countries. Many mobile carriers in developing countries are already deploying 2.5G and 3G networks, just to keep up with the explosive demand for voice and (SMS) text messaging services, and for the same reason it is likely that such carriers, not those in the industrial countries, will drive the demand for 4G (next generation) wireless networks. Already, the collective buying power of developing world carriers has resulted in a contract (won by Motorola) to produce a basic GSM phone for about \$30. Nokia has also developed a low-cost "entry" phone. Since the dominant market for new networks and new and replacement phones will be developing countries, the equipment providers are now paying close attention to their needs.

The bottom line is that, for the vast majority of people in developing countries, their "PC" and Internet access device will be a mobile phone, a handheld computer, or a hybrid of these devices. An example is the new Apple iPhone, whose introduction and design qualities are likely to drive impetus, competition,

and increased attention to this platform. At the moment, attention is focused on high-end users and high prices, but that is likely to change within five years, driven in part by the huge volume of potential users in developing countries. Hence it is important for Hewlett to consider how this platform can serve the needs of education.

A second major trend is the rapid evolution of fixed wireless broadband networks, the Wi-Fi family (802.11), and the newer and longer-range Wi-Max family (802.15). These are spread-spectrum radio technologies very similar to those used in mobile phones, but they are newer, optimized for data rather than voice, with much higher throughput capacity and generally less expensive equipment—in large part because they are based on industry-wide standards that are attracting many manufacturers. They can operate in both licensed and unlicensed (free) parts of the radio spectrum. A still evolving mobile Wi-Max standard may become the 4G technology of choice for mobile carriers. Wireless Internet Service Providers (WISPs) based on these technologies are proliferating in the United States and are about to take off in Europe. But the critical point here is that the low cost of these technologies and their rapid rate of evolution may provide a route to affordable broadband coverage even in rural areas of developing countries.

The model system has a number of components, as follows: Wi-Max-fixed wireless or new generation satellites (designed for IP-based traffic) as backhaul links to reach rural communities; advanced Wi-Fi mesh networks within such communities or to link a group of communities; and, initially, Wi-Fi-enabled phones including multi-mode mobile phones or PC-phone hybrids that provide Voice-Over-Internet-Protocol (VOIP) voice service.¹⁹⁵ New “smart” mesh networks can be deployed without an engineer, can be remotely monitored, draw so little power that they can be solar-powered when needed, and can provide service up to several kilometers from the access point. A significant list of applications, agricultural information, financial services, health alerts, instant translations, and educational services can be delivered via such phones and voice-based systems. This model has already been deployed in rural Mongolia, where it is rapidly being commercialized, and a larger deployment in Vietnam is in the planning stages. (See Next Section.) The central features of the model are: (1) the user interface is a phone, with minimal tech-support or literacy issues; (2) it provides voice service at radically lower cost than any switched network. For calls within a local rural network, which accounts typically for about half the traffic on a local phone system, the cost is essentially zero; for calls to other Internet phones, the cost, like a Skype call, is minimal. Only calls into the switched network need incur significant tolls. And (3) it is a broadband network capable of supporting PCs, advanced mobile phones, or other Internet

¹⁹⁵ For more details, see “A New Model for Rural Connectivity,” by Al Hammond and John Paul, posted at www.nextbillion.net.

access devices as needed. As a figure of merit, the estimated network capital investment required to cover all rural communities in a one million inhabitant province of Vietnam comes to \$2.50 per person, and the bandwidth cost (for VSAT links that provide up to 2 Mbps per rural community) is less than \$1 per year per rural household. These figures are a factor of twenty below the conventional wisdom for rural connectivity costs. However, it is important to point out that they depend on a policy environment with allocated frequencies for VSAT or Wi-Max, with free Wi-Fi spectrum, and with VOIP legally permitted, which is not yet the case in many developing countries. But if this model gains traction, or if mobile network coverage expands further into rural areas while evolving as described above, then broadband access in many rural areas may well become feasible within five years.

It may be useful to put the specific discussion above in a slightly broader context. Recent research on household expenditure patterns in low-income communities being conducted by the World Resources Institute and the International Finance Corporation (World Bank Group) makes clear that there is substantial purchasing power in low-income communities, over \$5 trillion worldwide, aggregated across four billion people. Moreover, ICT expenditures are found at nearly all income levels, and rise sharply as incomes rise; in fact, expenditures on ICT rise proportionately more than expenditures in any other sector, perhaps reflecting awareness that access to connectivity boosts welfare and productivity. An *Economist* cover story in 2005 reported on research documenting the social impact of mobile communications in low-income communities in Africa, in finding work, in getting medical attention or other help in emergencies, in keeping far-flung families (of migrant workers) in contact, and in substituting for expensive and time-consuming transportation, among others impacts. Over the past ten years, ICT (and especially mobile telephony) has emerged as one of the few clear successes in helping alleviate poverty and accelerate economic and social development.¹⁹⁶

Some implications for education. Driven in part by security concerns, automated translation is improving very rapidly, which could help make educational content (including audiovisual content) available in local languages at less cost. Secondly, the availability and ease of use of images and voice, as opposed to text, other than short messaging, on mobile phones suggests that expanded use of these media to deliver educational experiences should be strongly considered. Thirdly, the rapid evolution of online gaming, and its evident appeal to youth in developing countries (it is becoming an important source of revenue for cyber cafe operators, even in rural parts of developing countries), suggests that participatory educational modules based on gaming technology would gain rapid acceptance. And finally, as suggested above,

¹⁹⁶ The Next 4 Billion: Market Size and Business Strategy at the Base of the Pyramid, World Resources Institute and IFC, forthcoming 1st quarter 2007.

consideration of mobile phones or hybrid handheld devices as a platform for delivering educational materials and services deserves a high priority. To the extent that PC's are required or desirable, at least for rural areas, venues with fixed wireless broadband networks should be sought out or established.

5.3 Venues Ripe for Testing

As suggested above, a number of factors are required to create an enabling environment suitable for affordable broadband access, especially in rural areas. A good starting screen would be reliable electrical grids, available in much of Latin America, in much of China, in some Southeast Asian countries such as Thailand and Vietnam, and in South Africa; in other regions, national or subnational grids need to be examined separately (Indian states vary significantly in the quality of their electrical supply). Another important indicator is mobile phone coverage, which reaches close to or above 90 percent of the population in many developing countries: There are South Africa (96 percent), Botswana (85 percent), and Senegal (85 percent) in Africa; many countries in Latin America, for example Argentina (95 percent) Chile (99 percent), Columbia (94 percent), Ecuador (88 percent), El Salvador (86 percent), Mexico (86 percent), Venezuela (90 percent); and a few in Asia Thailand (92 percent), Indonesia (85 percent), Cambodia (87 percent), and Malaysia (96 percent). Most countries in North Africa and some in the Middle East have good coverage, too: Algeria (84 percent), Egypt (91 percent), Morocco (95 percent), and Jordan (99 percent). Coverage in larger countries is usually lower (73 percent in China, 68 percent in Brazil, 78 percent in Russia, 41 percent in India) and will vary from province or state to state.¹⁹⁷ The existence of strong competition among both broadband and mobile phone providers is perhaps the best indicator that coverage will expand, costs will decline, and new technologies and services will be rapidly incorporated. A compelling illustration of this is the difference in phone density between the Democratic Republic of Congo, which has six mobile operators, and Ethiopia, an equally poor country with only a single operator: The Congo has thirteen times the phone density of Ethiopia.¹⁹⁸

A decade ago, mobile telephony was the new entrant in developing countries, often resisted by the legacy wireline telcos and governments closely allied with them. Now mobile carriers (and many governments) are resisting still newer technologies such as VOIP and fixed wireless. VOIP is still illegal in many developing countries, although there is widespread private usage and the trend is toward legalization, and many countries have not assigned frequencies for Wi-Max or VSAT deployments. A few countries are notable for the creativity of the mobile companies operating there, especially in introducing business

¹⁹⁷ World Bank, *op.cit.* tables; data as of 2005.

¹⁹⁸ World Bank, *op.cit.*, p. 43.

models that reach low-income populations and financial services over mobile phones, especially the Philippines and South Africa, which may make them good pilots for educational experiments.¹⁹⁹

Vietnam as a Laboratory. The involvement of one of the authors in a rural connectivity project in Vietnam means that more detailed information is available for this country, examined here as an in-depth case study. Eighty percent of the population is rural, and 32 percent is under the age of 15, still a very youthful population with high education needs. The economy is accelerating; Vietnam is joining the WTO this year and already has a bilateral trade agreement with the United States; and the government is ranked highly in World Bank Doing Business surveys for reforms of its enabling environment. English has been taught in schools as a second language for twenty years. In the ICT space, both ISPs and VOIP are legal, there is fully commercial VSAT service, and tentative Wi-Max frequencies have been assigned. There are two competing broadband providers, both building national optical fiber loops (in Vietnamese style, both are nationally owned entities that operate as private companies), and three mobile phone providers. Mobile coverage reaches 67 percent of the population but is quite spotty in mountainous rural areas. In practice, many rural communes do not have phone service and virtually none have Internet access, although they usually have electrical power. Most rural households could not afford mobile service, typically a minimum of \$7 to \$10 per month. Vietnam has just signed an agreement with Rice University to make its open curriculum platform, Connexions, the basis for the country's effort in this area. Two new national initiatives could impact rural connectivity: a new Universal Service Fund can provide zero percent equipment financing for service to rural communities, and a new rural infrastructure effort designed to integrate rural areas into the economy that is heavily financed by a group of donors, Program 135, is looking for province-scale models to implement nationwide.

In this context, a pilot connectivity pilot is taking shape in Quang Ngai province, a poor and largely rural area of one million people in the middle of the country. The pilot, to be managed jointly by the provincial government and World Resources Institute, will implement the VSAT/Wi-Fi/VOIP model described above in three rural communes (each of which includes three to five villages of varying size) chosen to span different topographies and ethnic groups, with support from AusAID and USAID. The provincial government has made clear its intent, if the pilot is successful, to use national funds from one of the programs described above (Universal Service Fund or Program 135) to build out the entire province (156 rural communes, or about 160,000 rural households). Preliminary estimates are that the VSAT/mesh Wi-Fi

¹⁹⁹ See case studies on Smart Communications (Philippines) and Vodacom (South Africa) and other posting on Celtel (Zambia) and Whizit (South Africa) at www.nextbillion.net.

infrastructure could be installed across the entire province for a capital cost of about \$2.5 million. VSAT broadband leases (one per commune) cost \$900 per year for 2Mbps down and 0.5 Mbps up, amounting to less than \$1 per household per year.²⁰⁰ AusAID is supporting the project because it sees a potential provincial infrastructure model for national scaling. In addition, the Connexions project has expressed interest, since its partnership with the Vietnam Education Ministry is already in place and province-scale rural broadband access that could be applied to educational purposes does not otherwise exist in the country. There is also a nascent local software industry, and Intel is building a chip factory in Vietnam. The combination of these features may make Vietnam, still a relatively poor country, an interesting and fruitful laboratory for new, IT-based educational approaches.

For reasons advanced earlier, a number of other countries may also provide useful venues—the Philippines, South Africa, and any of several countries in Latin America.

²⁰⁰ The VOIP traffic will be managed with a “soft” switch residing on a PC that requires less than a second to establish a connection; for local calls, the traffic then stays within the local WiFi network and does not transit the VSAT link. The result is that approximately 1,000 households, a commune average, can share the VSAT bandwidth with little difficulty as long as VOIP is the main application and call volume remains modest (likely, these are agricultural communities). Additional VSAT links could be added when demand warrants.