Standing on the Plateau Looking Forward:

The Croquet Project

By

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Recently, I paid a visit to my university's website, where I found a campus slideshow for prospective students. Doubtless, you'll find a similar slideshow or virtual tour on your institution's site. And chances are you'll be met with image after image of young people lounging, walking, eating, sailing, and laughing in sun-drenched settings across campus. At the University of Wisconsin-Madison, they are sprawled on vast lawns in a perpetual summer ("a favorite place to study – and not to study" the caption reads); they enjoy the lakeshore view from our student union Terrace ("famous for its sights and sounds"), they take in the nightlife of downtown Madison ("no matter what time you walk down State Street, you'll end up seeing someone you know. You'll always run into someone different, someone new").

Deeper into the slideshow, students are actually pictured at work, but not in classrooms or lecture halls. They stand outdoors peering through land surveying instruments ("the advantage of out-of-class projects and research opportunities"), or gather around a computer terminal in an energetically cluttered laboratory ("research at UW-Madison is a participatory venture, in which students and professors often work side by side"). And in one astounding shot taken through a fish-eye lens, we peer down on an intrepid rock-climber as he reaches the top of a rather formidable campus wall. The quote that accompanies this picture pretty much sums up the general outlook: "Most of the lessons we learn here are not from lecture halls, not from books. They are from our experiences in life."

I would venture to say that similar sentiments are being expressed on university websites across this country. Through the medium of the campus itself, university communications offices offer prospective students (and their parents) the promise of *an experience*. Colleges and universities (particularly those with centralized campuses) promote themselves, first and foremost, as *places with people*. The physical campus sets up the enabling conditions for a

complex *social ecology* to emerge over time. Large numbers of students engage in daily role-playing (also known as "critical thinking") during which they "perform" a particular point of view, trying it on for size, explaining, critiquing, justifying, deepening, and reinforcing their understanding while strengthening their group identity. Ask anyone who has ever been through a rigorous program of study, and chances are they will remember learning more from their fellow students than from their professors.

The unique value of campus life, then, is a matter of *proximity* – the ability to position oneself in direct relation to relevant people and resources. Philosopher Erving Goffman called these spatially defined moments of engagement "focused gatherings" where "a set of persons [can become] engrossed in a common flow of activity and relating to one another in terms of that flow." The gathering takes its form from the situation that evokes it, "*the floor on which it is placed*," as Goffman puts it.[1] Add to this foundation, the ready availability of tools to forcefully express, embody, and exchange ideas, and the campus has all the makings of one vast "collaboratory."

So, how much of a role does campus life really play in effective education at the postsecondary level? Quite a vital one, if we judge by the enrollment statistics at the Massachusetts Institute of Technology. After all, MIT students are willing to pay more than any other undergraduates in America to enroll at the university, despite the fact that everyone in the world now has access to the lectures of its stellar faculty through the MIT OpenCourseWare Initiative. Why do students still flock to campus? Clearly, the big draws are neither courses per se nor curricula, but rather the intellectual *contact* and the highly charged social *context* that the MIT campus life can provide.

Despite all this, we continue to design online learning environments that do little more than replicate the remoteness of a lecture hall. Clearly, any approach to online education that restricts itself to the delivery of pre-packaged content alone ignores the depth and social texture of campus life, along with the collaborative nature of learning. Of the three broad aims of higher education as identified by learning researchers — 1) skill acquisition and competence with tools and techniques; 2) socialization and induction into the canons of particular communities, professions or disciplines; 3) development of an intentional, or self-directed, approach to life-long learning — current online learning environments are relatively successful in managing only the first, most transactional of goals.[2]

The Call to Action

Edward L. Ayers and Charles M. Grisham expressed the frustration of an entire generation of technology enthusiasts within the academy in their 2003 *Educause Review* feature article, “Why IT Has Not Paid Off As We Hoped (Yet):”

> In particular, we waited for a time when the very heart of education — the classroom and scholarship taught in that classroom — would be transformed [by technology]. But despite the tremendous investments that all institutions of higher education have made in IT . . . the vast majority of our classes proceed as they have for generations — isolated, even insulated, from the powerful networks we use in the rest of our lives. Moreover, the nature of *argument* has remained remarkable resistant to innovation in rhetoric or form in every field of scholarly endeavor.”[3]

Ayers and Graham, both academic deans and longtime educators, describe the problem as a failure of technology to touch “the heart of higher education — residential colleges and universities — [which] have remained relatively immune [to transformation].” They conclude “Why IT Has Not Paid Off As We Hoped (Yet)” with a resounding call to action:

> A far-seeing company, or consortium of companies, should establish an alliance with colleges and universities to build the ideal institutional environment to help lead the revolution from within, working with faculty to create tools that people will actually use, establishing new standards for enhanced teaching and scholarship, and creating a living, ongoing alliance. Now would be a great time to start — just when it seems that IT doesn’t matter.

But should we rely solely on the farsightedness of commercial vendors, whose priorities can differ markedly from those of educators and scholars? Along with co-author Jeremy Haefner, 2002 NLII Fellow Colleen Carmean published the important results of an NLII Spring Focus Session on “Next-Generation Course Management Systems” in *Educause Quarterly*.[4] The very fact that Carmean and Haefner felt the need to frame their recommended improvements to the standard CMS model as a “Wish List” reflected sadly on the imbalance of power that exists between higher education and CMS companies. Carmean and Haefner do all they can to coax

improvements out of vendors by justifying innovation as an effective business strategy: "Introduc[ing] faculty and students to [light Web versions of innovative tools] could serve as a strong marketing tool for the richer third-party vendor products." Uncertain that vendors will take them up on this suggestion, the authors end their essay on a note of supplication: "We know what we need, and we're easy to please . . . Feed us."

Tellingly, the traditional CMS was never meant to support innovative teaching practice, but was instead intended as an administrative "container" or set of "containers" for course *management* (connoting efficiency and restraint). Regardless of the number of "improvements" grafted onto the CMS platform, the conceptual framework will always give primacy to administrative matters over pedagogical experimentation. In point of fact, we have been *far too easy to please* until now, but as more and more faculty members commit themselves to using CMS's, vendors are likely to be confronted with a more demanding customer base. To put it bluntly, it's about time we learned to feed ourselves. After all, "give a man [sic] a fish; you have fed him for today. Teach a man to fish, and you have fed him for a lifetime."[5]

CMS's leverage only a small fraction of the learning potential that our expensive campus infrastructures are capable of supporting. Higher education leaders have outfitted their campuses over the last several years with fat pipelines and high-speed connectivity, making it feasible for educators to do far more than merely automate their traditional lecture courses. Students come to college equipped with the latest in commercially available PCs and laptops. Hard drives are bigger, graphics accelerators speed up 3D image display, and faster processing chips simulate real-world physics with relative ease.

As one analyst concluded recently, "proprietary systems . . . seem to have hit an early plateau" while "open source applications are standing on that plateau looking forward."[6] What remains to be seen is whether higher education leaders are willing to be proactive where their mission critical responsibilities are concerned. Will they move ahead of the curve to define the future of online teaching and learning? Knowing what we know now about the power of computing and networking technologies, what would we do differently?

For the open source developers at work on the Croquet Project, these are not merely rhetorical questions. Croquet open source developers are engaged in a concerted effort to move beyond computing paradigms that have been in place, largely unchanged, for the last thirty years. The

project draws on the talents of the entire open source development community, including university-based educational researchers, along with visualization and simulation specialists. Forming around the Croquet Project is a far-seeing alliance of educational and corporate partners, led by the University of Wisconsin-Madison and the University of Minnesota-Twin Cities. Educational institutions are lending their expertise and support to the development of a next-generation learning platform based on the novel Croquet communication and collaboration technologies. Inspired by the precedent and paradigm of the residential campus, Croquet educational developers are working to carry the primary advantages of campus-based learning over into the online realm, making the online learning experience far more personally involving, meaningful, and rewarding than it is today.

The Campus Learning Space: Precedent and Paradigm

Over the centuries, successive generations of teachers and learners have expressed their specifications for the ideal learning environment through the medium of the residential campus. At once timeless and dynamic, the campus has become the learning space against which all other learning environments are measured, expressing and shaping our educational philosophies and practices. The Croquet Project educational partnership is paying close attention to the physical spaces *between* the classrooms where the life of the campus so often resides. Although the definition of a campus, strictly speaking, is "the open space between and around the buildings," the Oxford English Dictionary suggests that the word "campus" has always alluded as well to the kinds of human interactions that take place there. These interactions, taken together, make up what we call "campus life." Housing, preserving, and conserving the best that is known and thought in the world, the campus buildings and grounds lend a sense of persistence and continuity to a student's experience over time.

If residential colleges and universities are the modern physical expressions of certain deep-seated educational ideals and values, how might we reflect these special qualities in our online learning spaces as well? Alternatively, how might a virtual learning space prove more flexible and responsive to dynamic alteration than a physical classroom setting? One approach to addressing these questions would be to imagine that the physical campus was actually a virtual environment conjured from programming code and messages beamed across optic fiber. What challenges would a genuinely immersive digital "campus" face in its efforts to support the kinds of activities we take for granted in a real-world context?

To pursue these questions, I begin by offering the reader a feature guide to campus life, including essential information on usability, network architecture, accessibility, and design principles. I will be borrowing terms such as “interoperability,” “scalability,” and “platform neutrality” from the realm of computer technology to draw attention to the kinds of inclusiveness and accessibility built into modern campuses – qualities that continue to elude us in the online learning realm. By emphasizing the relative freedom of movement we enjoy within the campus “information space,” I underscore the role that incompatible operating systems, applications, and formats have played in making online learning a remote, cramped, and emotionally “flat” experience. From there, I will introduce the open source Croquet Project, examining the practical steps that researchers and technologists are currently to deepen and transform the way we teach and learn online.

As a platform for learning, the residential campus is unsurpassed. It gains its unique strength from the following features:

- ***Platform Neutrality***. Campus architects and planners do not design technical barriers into the campus infrastructure for the sole purpose of preventing people from seeing the campus as others see it, or accessing information to which they are entitled. In fact, quite the opposite is true. Accessibility to public areas is a campus priority.

- ***Synchronization of Real-Time Interactions.*** When something happens on campus, everyone in the immediate vicinity sees the event simultaneously. Groups of people can explore and react to everything others are doing *as they are doing it.* This also means that time-limited events (including lectures, films, and concerts, etc.) may be experienced by large numbers of people simultaneously. Even browsing the Web can become a communal experience. “Over the shoulder computing” where a group of students share a single terminal to browse the web is a commonplace on campus. Compare the isolation of the off-campus computing experience with the possibilities that the campus provides for collaborative research.

- ***Distributed Architecture***. Imagine how vulnerable our academic institutions would become, if we stored all of our classrooms, our administrative records, and learning materials in a single building. After long experience, campus planners know a few things about backup,

redundancy, and distributed resources. Each campus facility has its own "firewall," or securable set of entryways, providing multiple failsafe points against potential disruptions. By distributing classes and departments across a wide area, the modern campus is built to make certain that a break-in at one end of campus will not take the entire institution down.

- ***Identification, Authentication, and Authorization Mechanisms.*** While permissible forms of expression are under continual negotiation, there are two mechanisms that a university or college campus uses to secure itself against vandalism and malicious intent: 1) policing and 2) peer pressure. The latter does more than anything else to curb inappropriate behaviors since an action performed in full view of others can be traced back to its source. Status and reputation are the social capital of campus life. Consider the last conference you attended and the power of the simple nametag to establish identity and curtail disruptive behaviors. Is it any surprise that 70% of the money invested in information technology has been spent to overcome the anonymity and "statelessness" of the Internet?

One key to the success of the campus platform is its remarkably persistent graphical user interface:

- ***Persistence*.** The campus persists over time. If you plan to return to a particular spot on campus, you can be confident that it will be there in much the same condition as you left it an hour, a day, or even a year ago. Since the campus is unlikely to disappear into the ether the moment you turn your back on it, you can make some long-term commitments to the people you encounter there.

- ***Statefulness.*** Persistence is a pre-requisite for "statefulness." If our campuses were as "stateless" as the World Wide Web, there would be no such thing as institutional memory. Everyone would be afflicted with collective aphasia. Professors would be incapable of remembering what they or their students were doing the last time class met. Try assessing a student's growth over the course of a semester, when your memory is wiped clean after every class session. Consider how much money it would cost to overcome such failures of memory. Luckily, the persistent campus world provides plenty of daily opportunities for people to grow accustomed to one another's faces.

- ***Temporal Continuity.*** The persistent campus environment offers students a way to understand their development as a *continuum*. Since each discipline occupies its own niche in the campus ecosystem, a student can chart her progress through the curriculum as a movement in space as well as time. While she works her way from the periphery towards the center of her chosen discipline, new campus venues, new conversational niches, and new contacts open up for her as well.

- ***Spatial "Proximality" and Serendipitous Discovery.*** The campus is an "information space" where people co-exist with concrete, tactile, and manipulable objects of learning. Mobile people are able to situate themselves in relation to like-minded colleagues within a shared workspace where relevant tools are ready to hand. The campus library is both a repository for catalogued ideas and a browsable emporium for ad hoc discovery. Proponents of "constructivist" and "situated" pedagogies argue that closeness to objects supports a particular relationship between the self and learning. MIT researchers Sherry Turkle and Seymour Papert argue that "proximality" is a crucial component of effective learning for "people who primarily relate to the real world through movement, intuition, and visual impression" and make their discoveries in a concrete, ad hoc fashion.[7] For these learners, the campus commons can provide a respite from the formalism of the lecture hall. If lectures often ask students to view the world from a highly structured, analytic, and abstract perspective, the campus presents them with an alternative "port of entry" into the complex areas of thought. The ready availability of people and materials makes the campus a perfect arena for bricolage, or the creative reassembly of "whatever is at hand." The medium of the campus is itself an inspiration, suggesting adaptive courses of action that are event-driven and spur-of-the-moment rather than planned.[8]

- ***Situated Knowledge***. An institution of higher learning signals its long-term investment in a particular line of study by awarding to that discipline its own location – its own niche in the campus ecosystem. Each department and discipline is attached to a particular location so that people can locate themselves and others in direct relation to the ideas that interest them. Thus, the campus provides the enabling environmental conditions for "communities of practice" to organize themselves around *a shared location* as well as a shared history and common repertoire of knowledge.[9]

- ***Media Aggregation*.** Books, papers videos, audios, television, photographs – individual media as conventionally understood — are themselves *subsumed* within the all-encompassing *"meta-medium"* of the campus. As a single, integrating environment, the campus provides both *the tools* and the shared *context* for creative processes to play themselves out and for a growing body of shared information to be accumulated and stored.

- ***Appropriately Contextualized Course Management*.** On campus, course administration occupies a discrete space in the lives of faculty and students, both literally and figuratively. Issues of enrollment, scheduling, facilities assignment, and grading, while absolutely vital to the smooth functioning of the system, do not normally intrude themselves on the classroom experience (unless something has gone seriously wrong). As far as the student is concerned, there are campus buildings that house administrative operations. The Registrar does not set up a table in the middle of the classroom. When a student enters class, she is never asked to step into an isolation booth for the duration of the class period. Neither will she be forced to sit at her desk wearing blinders, confining her view to the book opened on her desktop. If she wishes to communicate with the instructor or her fellow students, she does not have to scribble a note, pass it to the appropriate address, hope that it gets to its destination, and wait for a response that may or may not arrive days later. No, these are the parameters of the online learning experience, where all social interactions and learning materials have to be *shoehorned* into a cramped two-dimensional "window." By contrast, the real-world setting offers 1) a multi-dimensional environment where learning materials in a variety of media (text, slides, overhead transparencies, video and audio recordings) can *co-exist* within the same space as the people who use them; and 2) synchronized co-presence, making it possible for students to see the actions of others as they are performing them and to focus *as a group* on the same book, slide, or common activity.

The campus platform boasts a wealth of advanced group collaboration tools:

- ***Integrated Real-Time Communications***. Needless to say, people are embodied presences to one another while on campus, and can speak with one another using their natural voices. People signal their interest in joining a conversation by drawing closer to others – e.g. within hearing distance.

- ***Flexible Affiliation and Workspace Creation***. The living campus is a place where people can affiliate flexibly. Consider how easy is for an impromptu conversation to turn into an ad hoc study group. With little advance notice or coordination required, students are able to bring their resources with them and set up shop in an unused lab or commandeer a few tables in the student lounge. This has important consequences when it comes to fostering student-assisted or "peer-based" learning.

- ***Shared Content Creation*.** There is no such thing as a "read-only" campus. The campus commons is an interactive information space, a "writeable web" where new artifacts are continually emerging. The campus, studded with tools and materials ready-to-hand — everything from kilns and printing presses to confocal microscopes and gene sequencers – is a "collaboratory" of enormous proportions. The grounds – e.g. the space between the buildings – undergo extraordinary changes throughout the year, transformed by bleachers, sidewalk drawings, posters, leaflets, and temporary exhibits that may become permanent fixtures by popular acclaim. In this way, the common areas play off against the structural demarcations of large lecture halls, where the distinction between the lecturer as content creator and the students as content consumers is rigidly reinforced.

As with every learning platform, the campus suffers from a few disadvantages, stemming in this case from the campus's stubborn adherence to Euclidean geometry. Might a simulated learning ecosystem — one with all the features highlighted above — have any advantages over a 'bricks and mortar" counterpart? Consider the following possibilities:

- ***Scalable Personalized Learning.*** Colleges and universities with tens of thousands of students face an "instructor bandwidth" problem without an affordable on-campus solution. While personalized instruction remains an ideal, the instructor can only be stretched so far. Network architectures, on the other hand, promise to support learning environments where personalized instruction can be offered to large numbers of students. The Internet, with its vast peer-based communities (eBay, Slashdot, and the many massively multiplayer online gaming worlds) may offer a glimpse of the future for higher education. Cost-effective and scalable, the self-organizing online learning community taps the resources of students themselves, with a variety of fringe benefits. Rather than task the limited bandwidth of a single instructor, the community draws on the distributed expertise of the group as a whole. The value of the communal knowledge base will actually grow as the number of students

increases. The more “peer-to-peer” exchanges the network architecture enables, the better. Here is a learning environment for college-age students weaned on the Internet, Playstation, and XBox Live. As described by Harvard professor Chris Dede, these “neo-millennial” learners will demand to organize themselves from the bottom-up (co-organize), personalize their learning experiences (co-design), draw on the expertise of their peers (co-instruct), engage in contextualized learning-by-doing activities (co-construct), and use multiple media to demonstrate what they’ve learned.[10]

- ***Unlimited New Construction*.** Campus construction is a lengthy and tedious business typically involving capital campaigns, legislative fiats, and endless delays. Inflexibility limits the immediate usefulness of the physical campus for constructivist learning. Modifying a campus space is typically restricted to shuffling a few chairs around in a classroom. Think, however, of the possibilities that open up when the campus is virtualized, and people can see one another’s actions. With the right software and networking technologies in place (more on this later), a computer simulated “meta-medium” would respond to human manipulation with unprecedented ease. New 3D spaces for private discussion or public exhibitions could be created with a simple click of a mouse. Students might demonstrate their knowledge of a subject by modeling a molecule in three dimensions or fine-tuning a weather system simulation. Once the authoring of 3D models and simulations becomes as quick and inexpensive to accomplish as web page publication is today, educators will be able to provide enough evidence to document the benefits of a pedagogy based on concrete visualizations of abstract concepts and “learning-by-doing.

How close are we, in truth, to an online learning environment that captures the social vitality and collaborative spirit of the real-world campus? Closer than you might think.

What is Croquet?

Imagine you are a graduate student in astronomy asked to demonstrate your knowledge of Kepler’s Laws. You launch a software application on your computer and enter a three-dimensional online world. Inside this environment, you use the drop-down menu to quickly design and deploy a dynamic simulation of the solar system. As your simulation runs, you see your professor enter the lab and move in for a closer look. Your professor downloads a file from his own hard drive into the virtual laboratory and it appears inside a display window he just

created with a click of the mouse. Remarkably, you and your professor are now able to see one another make additions and changes to the same document, all the while keeping up a steady banter with the help of network-enabled telephony built into the software system. Your professor is impressed by your work and so he invites his entire introductory astronomy class to a viewing and discussion of your simulation. From across campus, hundreds of students gather inside the virtual lab. The instructor's video image (captured by the web camera on his laptop) is visible to the groups of students he guides through the demonstration. Classmates wander among the planets, adjusting the timing and motion of the celestial machinery, talking with one another over network-enabled telephony, gaining an unprecedented appreciation for Kepler's laws in action.

This vision of the future in computer-mediated education is driving the efforts of the open-source Croquet Project. For higher education, Croquet promises to place the learner inside a three-dimensional online world with scores of other learners and educators, all computing collaboratively and communicating naturally through videoconferencing and network-enabled telephony. Croquet runs on top of operating systems like Windows, MacOS, and Linux. The project has been designed from the start to make the most of advanced campus networks and the untapped computational resources of individual machines by enabling safe, secure, and creative *cooperation* – among machines, among user interfaces, among content developers, among users, and among institutions. The result of their efforts, it is hoped, will be a next-generation online learning environment that captures the social vitality and collaborative spirit of the real-world campus.

Croquet is the brainchild of its six core architects — Alan Kay, David A. Smith, David P. Reed, Julian Lombardi and Mark P. McCahill — all leading figures in their respective fields brought together by Kay, winner of both the 2003 Turing and Charles Stark Draper Awards. Famous for his design of the now familiar desktop metaphor for personal computing, Kay watched (with little enthusiasm), as his overlapping windows interface became an entrenched part of the contemporary business world with the introduction of Microsoft's Windows operating system.[11] Always an innovator, Kay insisted that the new age of networked computing demanded a new interface standard for collaborative work and learning. With the Croquet Project, Kay would place personal information management in a multi-dimensional and highly social context by capitalizing on the remarkable advances over the last decade in broadband communications, computer processing speed, and graphics acceleration.

The now ubiquitous page-based convention for human-computer interaction had always been a stopgap for Kay. He continues to have a larger vision for computing and the role it could play in the daily lives of everyone, particularly children. For Kay, computing would only live up to its full creative potential when anyone could program exciting, interactive experiences for other people. In the best of all possible worlds, programming would no longer be the exclusive domain of professionals.[12] Kay shares with researchers like Seymour Papert and Sherry Turkle a belief in the democratizing potential of the computer itself as tool and expressive medium: "the computer, with its graphics, its sounds, its text, and its animation, can provide a port of entry for visual and experiential learners into formal schools of thought that might otherwise elude them, from physics and mathematics to musical composition." And there is mounting evidence that concepts which remain opaque when viewed as equations in a textbook – economic models, multivariable calculus, molecular interactions – come alive when visualized through dynamic computer-generated simulations and 3D models. Moreover, the computer should give students the ability to move beyond passive viewing toward active engagement with simulations as they are running. Kay's ideal learning platform, then, is one that hands average users the tools and the "studio space" to co-create interactive experiences and to manipulate those dynamic simulations *while they are running* in real-time.

Based on a derivative of Kay's Smalltalk programming language, the Croquet system is meant to provide a single, integrative learning environment that places the power of programming in the hands of technical novices and experts alike. For its architects, "Croquet has been focused on high bandwidth collaboration from its inception. Simply put, the fundamental building block of the Croquet architecture is a system that makes every single object [inside the 3D world] collaborative." The Croquet virtual environment is unique in its ability to subsume a variety of so-called "legacy content" for viewing within a shared multi-dimensional context. Once a document or program is uploaded into the virtual environment, that course syllabus or presentation slide automatically becomes a Croquet "object" – meaning that it is instantly open to co-browsing or co-editing by groups of people in real-time.

Moreover, the Croquet virtual environment will offer users a host of integrated 3D development tools. The environment is designed to support people who wish to build complex 3D models and dynamic 3D simulations either singly or collaboratively. As the Croquet architects describe it, "we are creating an environment where anything can be created, everything can be modified, all

while still inside the 3D world. There is no separate development environment, no user environment. It is all the same thing."[13]

What are the current challenges?

Already, the Croquet environment displays more creative flexibility and responsiveness than its nearest relative, the massively multiplayer online game world. Positioned anywhere inside the vast Croquet learning space, a user can open up a new picture window or archway with a click of the mouse – and then step through it into an entirely new 3D world. These new "sub-spaces" are like antechambers, all leading back to the main world. They might serve as private zones for managing personal resources or collaborative workspaces for groups of students to display their documents, videos, animations, or simulations for collective review. The Croquet Project got its name, in fact, from one early observer's association. With its multiple archways and moving 3D objects, the virtual environment reminded him of an image from *Alice in Wonderland* – specifically, the bizarre Croquet game where flamingo "mallets" struck hedgehog "balls" through bent playing cards substituting for "wickets."

Still, complex challenges do lie ahead for the Croquet's architects and the project's growing cadre of open source contributors. One glance at the feature guide to campus life described earlier will reveal the enormity of the task the Croquet Project has undertaken. Campus life as we know it depends to a great extent on its traditional "architecture" for social networking. Bricks, mortar, and manicured grounds provide the common staging area for natural, real-time conversations. Inside classrooms, actions are authenticated and synchronized, while groups of students and teachers are able to access information and create content collaboratively.

In order to capture these fundamental properties, Croquet software will have to run on a network with four basic components in place: (1) an authentication component responsible for controlling access to the world and entitlements within it; (2) a communication component that determines how participants send messages to each other; (3) a storage component to ensure that the basic state of the shared world persists over time; and (4) a computation component to schedule real-time changes in the online world brought about when participants reposition themselves, add to, or alter the environment in any way.

- ***Authentication***. At the institutional level, the prospect of interpersonal, inter-institutional and cross-institutional collaboration inevitably raises trust concerns. Any new platform must be able to leverage the rights management systems already in place at participating universities. Removing anonymity from transactions within the shared environment will ensure that the creative commons is respected, disreputable behaviors are not encouraged, peer recognition and review becomes a socializing force, and individual contributions to group research projects are credited to their rightful authors, leaving institutions with a useful record of peer-reviewed faculty achievement in teaching and research. Efforts are currently underway at the University of Wisconsin-Madison to leverage the university's own university directory service so that members of the Madison academic community will be able to enter into trusted collaborations. Meanwhile, the Croquet development teams in Wisconsin and Minnesota are working with Internet2's Signet middleware initiative to devise the identification, authentication, and authorization mechanisms necessary for cross-institutional collaboration.

- ***Real-Time Communications***. Croquet developers have built the platform specifically to accommodate the synchronous voice and video communications made possible by Internet2 level advanced networks, which they regard as the future foundation for collaborative online learning and instruction. In this respect, Croquet is intended to serve as an integrative user interface for Internet2 services, including peer-to-peer applications, high-definition videoconferencing, remote manipulation of lab equipment, and distributed computing.

- ***Persistence.*** While it is one thing to provide space for transient activities that need not be preserved over time, it is quite another to offer users a semi-permanent base of operations that will persist between work sessions. Lombardi and McCahill plan to accomplish this goal by storing data about the environment on computers that never sleep – machines they call "super peers" or "interactivity servers."[14]

- ***Synchronization.*** The objective for Croquet developers is to design a *scalable* way of synchronizing activities inside the 3D learning environment so that participants can see one another change positions and add new objects inside the 3D online workspace without a glitch (without so-called "latency" or delays between cause and effect). In a flight simulation environment, for example, networked gamers engage one another in air battles and are

continually changing their position relative to one another. Like most commercial game environments, flight simulators typically use a client/server architecture to compute and schedule real-time changes. One combatant's machine sends information about his position to the central server. The server does the calculations and then sends messages about the player's position to all the other combatants in the immediate vicinity. But this client/server architecture for synchronizing real-time behaviors has several disadvantages:[15] (1) visible delays between cause and effect since every message has to pass first through the central server; (2) server overload as the number of users increases; and (3) the size and richness of the persistent world is limited by the storage capacity and processing power of the server. Gaming companies simply deploy more and more servers to meet demand. But this is an expensive solution that colleges and universities would be reluctant to embrace. The Croquet *distributed* messaging architecture has the potential to overcome these problems by allowing users to send messages directly to one another instead of forwarding them through a central server. Lombardi and McCahill have proposed a mesh of interactivity servers as extensions to Croquet's decentralized messaging architecture because they appreciate that higher education has a duty to ensure accountability and trust relations within collaborative online learning environments. Their white paper "Design for an Extensible Croquet-Based Framework to Deliver a Persistent, Unified, Massively Multi-User, and Self-Organizing Virtual Environment," is available for download on the Croquet Project website. [16]

- ***Backwards Compatibility for Media Aggregation.*** Reviewing our transition from older information systems to the World Wide Web, we can recognize how important it was for Web architects to provide early users with gateways back to older systems such as Internet Gopher and the "legacy content" these systems contained. To ensure a similarly smooth transition between paradigms, the Croquet developers intend to make it possible for early adopters to access the applications they are accustomed to using (for emailing, word processing, and spreadsheet preparation) *without ever having to exit* the integrative Croquet space. Croquet will include a full-featured Web client, so that the legacy content of the Internet is accessible from inside the Croquet-based simulation.

- ***Contextualized Course Management***. All content created for delivery over the Web will be accessible within the Croquet collaborative environment, subject to the proper authorization, including content currently viewable from within course management systems, which have

become the widely accepted means of online learning delivery for universities and colleges. By repositioning course content within the context of a populated and immersive virtual environment, the Croquet developers hope to simulate the dynamics of campus-based learning.

- ***Open Source 3D Content Creation*.** Croquet will be a combination 3D development and delivery platform for educators. As Wendy Richards and Diana Oblinger remind us, "Without clear examples of gaming and simulation specifically designed for postsecondary education – and without clear documentation of the benefits – leaders [in higher education] are hesitant to take action." So long as advanced programming skills and access to proprietary gaming engines for real-world physics continue to be prerequisites for simulation-based curricula development, the number of complete prototypes will remain low. At present, however, educators are being held hostage to the commercial priorities of gaming companies, priorities that rarely align with pedagogical goals. Educational researchers at media labs across the country end up producing what are known as "one-offs" – educational games and simulations locked in proprietary formats, built on top of licensed gaming engines. The modification (or "mod-ing") of some saber-rattling fantasy game into something pedagogically sound is an expensive and time-intensive proposition. It requires a graphics artist to produce new visual assets, and a programmer to script new behaviors, disable educationally irrelevant features, and spend long hours waiting for code to compile or graphics to render. In addition, a per-seat license has to be paid to the gaming company for every student user of the educational "mod," and this fee alone can run to $30,000 for a class of three hundred students. The Croquet system is designed to offer educators an alternative to commercial gaming engines and 3D developer's tools for the collaborative creation of educational simulations.[17] Much as a current "wiki" Web site provides a single environment for reading, editing, and sharing Web content, Croquet offers a unified environment for creating, editing, and sharing 3D objects or dynamic simulations. The Croquet platform already provides access to a physics engine, the OpenGL graphics library, and a late-binding scripting language so that developers can actually see the changes they and their collaborators are making to the 3D object while the simulation is running in real-time, allowing for instant visualization and revision.

- ***Federated Repository*.** So long as participants can contribute to and benefit from a common pool of 3D objects and simulations, novices will be able to draw on the expertise of

more seasoned 3D developers and the value of the common resources will grow exponentially as the number of members increases. To support this distributed model of 3D content development, a federated database must be integrated into Croquet's network architecture, ensuring that any object created within the framework is *automatically* attributed to its author, tagged with the proper descriptors, and stored in an extensible database for easy retrieval and re-use by any authorized member of the learning community.

If the expectations surrounding the Croquet platform are ultimately fulfilled, just think of the possibilities. Universities and colleges would have an *affordable* method of providing immersive online educational experiences. Researchers would begin to juxtapose evidence in new and unprecedented ways, studying data that extends far beyond traditional texts and images to include filmed testimony, oral history, architectural "walk-throughs," and interactive reenactments. Working within the Croquet environment, students could learn to argue as persuasively in the language of 3D simulation as they do in their native tongue – leaving them better prepared to enter an increasingly global and distributed workplace where this ability to "speak" in multiple media is highly prized.

Although the project's possibilities seem virtually limitless, Croquet will need to build a robust community around it in order to succeed. Programmers and educational application developers interested in familiarizing themselves with the Croquet programming environment are welcome to download a developer's preview of the technology from the Croquet Project website http://croquetproject.org/. A more complete release of the Croquet technologies is planned to appear on the Croquet website later this year.

Demonstrations of Croquet technologies already have attracted broad interest in the higher education sector. As of this writing, researchers and technologists from twenty universities have joined the higher education development effort, led by the University of Wisconsin and the University of Minnesota. All involved are working to ensure that the Croquet platform is able to address the special needs and concerns of higher education. The Educational Partnership welcomes new institutional members, universities and colleges ready to answer the call to action issued by Ayers and Graham for a "living, ongoing alliance [to] lead the revolution from within."

Will the next learning platform extend the vitality of campus life into the online realm? A growing open source community of educators and technologists is taking on that very challenge. Their timing couldn't be better.

(For more information about this paper or the Croquet project, please contact the author at mmlombardi@wisc.edu, or see the Croquet website at http://croquetproject.org/.)

Notes

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[1] Erving Goffman, *Behavior in Public Places: Notes on the Social Organization of Gatherings* (New York: Free Press, 1963).

[2] K.A. Bruffee. *Collaborative Learning: Higher Education, Interdependence, and the Authority of Knowledge* (Baltimore: Johns Hopkins University, 1993).

[3] Vol. 38, no. 6 (November/December 2003): 40-51.

[4] Viewpoint, *Educause Quarterly*, no 1 (2003): 10-13.

[5] Author unknown.

[6] Christopher D. Coppola, "Will Open Source Software Unlock the Potential of Learning?" Campus Technology: From Syllabus Media Group, December 2, 2004, <http://www.campus-technology.com/news_article.asp?id=10299&typeid=155/>.

[7] Sherry Turkle, Seymour Papert, "Epistemological Pluralism: Styles and Voices within the Computer Culture," *Signs: Journal of Women in Culture and Society* 16, 1 (August1990), pp.128-165.

[8] Sherry Turkle, Seymour Papert, "Epistemological Pluralism: Styles and Voices within the Computer Culture," *Signs: Journal of Women in Culture and Society* 16, 1 (August1990), pp.128-165.

[9] For more on "communities of practice" in the context of computer-based collaborative learning, see M. Scardamalia & C. Bereiter, "Computer Support for Knowledge-Building Communities," in *CSCL: Theory and Practice of an Emerging Paradigm*, ed. T. Koschmann (Mahwah, NJ: Lawrence Eribaum Associates, 1996).

[10] Chris Dede, 2004, "Distributed Learning Communities as a Model for Online Education," *20th Annual Conference on Distance Teaching and Learning* (Madison, WI) August 4-6.

[11] Kay received both the National Academy of Engineering's Charles Stark Draper Prize (considered the "Nobel Prize of Engineering") and the Association for Computing Machiner's

Turing Award (the "Nobel Prize of Computing") in 2003. Both awards testify to the range of his influence on the way we interact with computers today. Kay's pioneering work at Xerox's Palo Alto Research Center (PARC) in the 1970s led to Smalltalk, the first complete dynamic object-oriented programming (OOP) language. He and his research team at PARC also came up with a prescient vision of the personal computer that he named the "Dynabook," a computer with a three-button mouse and a new graphical user interface (GUI) remarkable for its overlapping windows. When Steve Jobs saw the "windowing GUI" and the mouse during a tour of Kay's PARC facility, he adopted it as the basis for Apple's Macintosh, which in turn gave rise to the Microsoft Windows operating system.

[12] Alan Kay and Adele Goldberg, "Personal Dynamic Media," *Computer* 10, 3 (March 1977): 31-41: "The ability to 'read' a medium means you can access materials and tools generated by others. The ability to 'write' in a medium means you can generate materials and tools for others. You must have both to be literate. In print writing, the tools you generate are rhetorical; they demonstrate and convince. In computer writing, the tools you generate are processes; they simulate and decide."

[13] David A. Smith, Alan Kay, Andreas Raab, and David P. Reed, "Croquet – A Collaboration System Architecture," 2003, http://www.croquetproject.org/About_Croquet/whitepapers.html

[14] Mark P. McCahill and Julian Lombardi, "Design for an Extensible Croquet-Based Framework to Deliver a Persistent, Unified, Massively Multi-User, and Self-Organizing Virtual Environment," 2004, http://www.croquetproject.org/About_Croquet/whitepapers.html

[15] For a relevant discussion along parallel lines, see Chris Gauthier Dickey, Daniel Zappala, and Virginia Lo, "A Distributed Architecture for Massively Multiplayer Online Games (draft), April 16 2004, <http://faculty.cs.byu.edu/~zappala/pubs/distributed-games-draft04.pdf.>

[16] http://www.croquetproject.org/About_Croquet/whitepapers.html.

[17] A groundswell of interest in harnessing those technologies for educational purposes is building within the academy, as evidenced by the adoption of "games, simulations, and technology" as a National Learning Infrastructure Initiative (NLII) "key theme for 2004."