This article will first look past the hype at the broader technological list of existing and proposed strategies, which may be grouped under the umbrella of peer-to-peer, in terms of both information and communications technology networks, and the applications, which can leverage those networks. This will lay a base for a discussion of what these strategies might mean for education, both in terms of fitting the contexts and missions of education and implications for educational technology planning.

The term peer-to-peer is nebulous. More recently it has been recognized as a buzzword based on a narrow interpretation, associated with high-profile applications as Napster and SETI@home. Gartner Consulting (2001) wrote that “Peer-to-peer computing (P2P) is currently touted as the next ‘killer application’ for the Internet.”

The Original Peer-to-Peer Network

As Oram (2001) pointed out, the concept of peer-to-peer networks is nothing new:

The original Internet was fundamentally designed as a peer-to-peer
system. Over time it has become increasingly client/server, with millions of consumer clients communicating with a relatively privileged set of servers. The current crop of peer-to-peer applications is using the Internet as it was originally designed: as a medium for communications for machines that share the resources with each other as equals. (p. 4)

Oram also pointed out that looking at the early applications, such as Usenet (facilitating newsgroups through the distribution and sharing of files, p. 5) and Domain Name System or DNS (the naming hierarchy supporting distribution to increased numbers of users, p. 7) which populated and enabled the “original” Internet would be informative toward efforts to realize further benefits from the peer-to-peer concept (p. 4).

Evolutions

During the mid to late 1990s, scaling and other requirements of commercializing the Internet led it away from the original peer-to-peer configurations. “Over time it has become increasingly client/server, with millions of consumer clients communicating with a relatively privileged set of servers” (Oram, 2001, p. 4). This caused the proliferation of tools and the deployment of network infrastructure, which are asymmetric in nature. Browsers are optimized for downloading rather than uploading or publishing information, and networks can efficiently distribute information only in one direction, becoming overburdened if asked to reverse the flow between servers and clients.

The recent crop of applications, both headline grabbing and the more subtle efforts, is only “using the Internet as it was originally designed” (Oram, 2001, p. 4). O’Reilly (2001) described the current tensions between client-server and peer-to-peer as an opportunity to “remake the peer-to-peer meme”

If we believe that peer-to-peer is about illegal sharing of copyrighted material, we’ll continue to see rhetoric about copyright and censorship at the heart of the debate, and may push for ill-advised legal restrictions on the use of the technology. If we believe it’s about a wider class of decentralized networking applications, we’ll focus instead on understanding what those applications are good for and on advancing
PEER-TO-PEER FUNDAMENTALS

Jones (2002) explained that there were “at least three distinct models for peer-to-peer computing.” He categorized them by the dynamic of the relationships that exist between the peers. A multiple peer relationship (e.g., Napster) allows anyone to share information with anyone else in the P2P network. The distributed peer (e.g., SETI@home) relationship is one that summates idle processing or other capacities of distributed resources toward solving a single problem, or set of problems. The last relationship, (as exemplified early by collaborative online gaming) is the collaborative peer relationship.

Gartner (2001) expanded this to a list of five “models.” Atomistic is the original P2P vision where all nodes connect directly between one another without any mediation. The disadvantage of this pure model is that it does not contain a method for establishing links based on either information or user parameters. User Centered P2P adds the function of a directory, which
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is based on user parameters. Data Centered of course, allows connections based on desired characteristics of information to be shared. “Web Mk 2” is what Gartner called (p. 9) “a convergence of all above models [Atomistic, User Centered and Data Centered] with current web architectures, which will be accessed by the next evolution of web browsers.” Lastly Gartner mentions Distributed processing, noting that it differs from parallel processing by using the Internet and being “opportunistic.”

O’Reilly (2001) takes the whole horizon of these applications into account in composing his “future meme” (Chart 2). He summarizes a number of potentialities (p. 56-58):

1. that the network can be seen as one giant computer;

2. P2P computing is “really about overcoming the barriers to forming ad hoc communities.” These communities may consist of information, users, devices, programs, and other distributed resources;

3. P2P has the potential to “break the IT bottleneck” and deliver much greater productivity; and

4. interoperability is the key to being able to discover all of the benefits that P2P strategy holds.


[Chart 2 not uploaded because of file size constraints]

PEER-TO-PEER IN EDUCATION

To understand how these complex opportunities may pertain to education, it is helpful to cast back to the earliest days of academic communities, as described in Brown (2000).

Though histories of the ’Net often assume that the past was another world entirely, these ’Net communities often assume that the past was another world entirely, the ’Net communities extend a long tradition
Brown went on to describe the history of the early scientific communities as it proceeded from letters, to printed “erudite letters” to journals. At the foundations of the Renaissance learning community, was an atomistic, peer-to-peer dynamic. Such accounts can support an argument that emerging technologies, before the appearance of commercialism, shaped a shift toward predigital “portals” and other bottlenecks, by having information converge in order to be further distributed. But each of these steps complicated the process and perhaps empowered otherwise undeserving agents with control over learning and knowledge. Now, technology has come full circle and disintermediation of the learning process is feasible. As O’Reilly noted (2001, p. 53) “Beyond the potential efficiency of such networks, peer-to-peer systems can help people share ideas and viewpoints more easily, ultimately helping the formation of online communities.”

Wiley and Edwards (2002) discussed “bandwidth” as a barrier to the formation of effective online learning communities, as it applies to the future configurations of online learning strategies:

The most significant bandwidth problem in online learning has nothing to do with pushing data through pipes. The idea of “teacher bandwidth” analogizes students to data, and teachers to pipes and formulates the problem thus: how many students can a teacher support in an online learning environment?

Although this potential problem is beyond the pure technical scope of peer-to-peer as discussed so far in this article, in general, it does foreshadow some unique issues to be brought forward amidst any future efforts to apply P2P strategies to online education. There will be a more extensive discussion of pedagogical issues later, but first, a brief discussion of infrastructure and the prospects for P2P being adopted in the educational operations environment.
Infrastructure

Higher education was the key partner in the original peer-to-peer network. Although the research activities of higher education mean that higher education is often on the cutting edge of new technologies, in terms of integrating these technologies once commercialized in its own service delivery operations, it often lags behind other sectors in adopting the cutting edge practical applications originally derived from their research breakthroughs (Hazari, 2001). What this means in terms of networking strategies in place, is that many higher education institutions have a patchwork of various disjointed client/server environments. These have been built up progressively in response to various needs and initiatives of many stakeholders. The research, pedagogical, and administrative functions all have built or adopted networks and applications based on a universe of influences, incongruous planning, and reactions to opportunities. Based on administrative and academic hierarchies, their architecture has belatedly followed the commercial model into client/server configurations, even as some leading edge proponents in the commercial sector contemplate the alternative P2P strategies.

Kumar, Merriman, and Long (2001) described the current stage in this proliferation of platforms:

The past two years have seen a dramatic upsurge in the preoccupation with “platforms” for supporting course administration, class management, and online education. These systems have certainly been useful in raising the floor for faculty participation in online education. . . This is important, and these all-in-one environments will likely continue to fill an important role for some time.

Educational applications and solutions have typically been localized in their orientation in that their value is realized differently in different contexts. Their development has also been inefficient and constrained because they have been able neither to leverage nor to integrate with existing enterprise systems. (p. 80)

In their program, Open Knowledge Initiative (OKI) at the Massachusetts Institute of Technology, they are proposing an enterprise architecture which is “modular” (Kumar et al., 2001, p. 81) one that brings intelligent extensibility in that it allows developers in different parts of the campus or at
different institutions to share their work without having to concern themselves with local implementations of the various common services. (Partners in OKI include Stanford, Dartmouth, North Carolina State, University of Michigan, University of Pennsylvania, University of Wisconsin-Madison, University of Washington, and the University of Cambridge.) The overall vision is to reconcile existing hierarchical legacy systems and existing tools with evolving functionality and unlimited capacity to grow and accommodate a diversity of stakeholder needs. “OKI’s architecture and open source approach is designed to encourage both the partner institutions and, later, a much broader community to contribute tools to OKI’s code base.” This configuration, which seeks to balance needs for control and security required by some functions is a common theme in P2P development and is reflected both in O’Reilly’s meme maps as well as in the categorizations of P2P approaches cited from Jones and the Gartner Group. It can also be characterized as a “hybrid” approach.

Developments in Open source are closely related to developments in P2P: “Both open source and peer-to-peer are technologies that allow people to associate freely, end-to-end, and thus are great levelers and great hotbeds promoting innovation” (O’Reilly, 2001, p. 49). One of the envisioned “tool” contributions to which OKI could extend would come from a coresident program at MIT, the Open Courseware Initiative, the freely available content repository being compiled from course materials generated from all MIT courses. Another term for learning materials, which have been developed to perform discretely and specifically within computer-based learning applications is “learning objects” (Wiley, 2000). Wiley wrote, however, that there is an underlying pedagogical conflict between P2P and learning objects. More discussion on that is offered next.

Internet2 (I2) is another high powered higher education/research initiative, which, through the power of applications combined with networking strategies based on a limited number of nodes with ample bandwidth is capable of defining potential P2P utility to support distributed peer learning (Barnes, Elliot, Entin, 2001). However, a review of the summary (Chinowsky, 2002) from a recent I2 workshop entitled Collaborative Computing in Education identifies a range of themes, which indicate this community views P2P as inclusive of threats, every bit as much as it presents opportunities: “P2P as a bandwidth hog; P2P and copyright; P2P for education; Resource discovery; P2P and other advanced networking technologies; Hybrid approaches.” These themes straddle both the old and new P2P meme maps. The notes
concerning education are general, vaguely identifying “great potential.”

As K-12 programs are generally driven by higher education and research, it is reasonable to assume that what will transpire in higher education will provide some trickle-down to K-12. The significant thing to note about K-12 networking is that the online and network infrastructuring effort is still relatively in its early stages, with many of the benefits of the investments in infrastructure and access to discounted Internet connections (e-rate program) still not yet fully leveraged. As a connection strategy, P2P networking is sometimes seen as a cost-effective strategy, but one which is not without its frustrations (Ellis, 2002.)

P2P strategies are currently more touted in the corporate sector, where in general “Peer-to-peer is now gaining traction as an unglamorous technique for making ordinary business processes more efficient” (Borland, 2001).

These business practices necessarily include the activities coming under separate but related headings of knowledge management (Woods, 2001) and training (Hoffman, 2002).

Hoffman (2002) pointed out:

To actually use P2P networks as self-directed training tools requires discipline. To create a working knowledge community, users must make content available and functional, and community members must take the time to search for content, clarify information, and provide feedback as to its usefulness. That requires a great deal of motivation on the part of the learner, but it’s not all that different from the motivation required to be a successful e-learner of any kind.

But perhaps the “discipline” idea is all wrong, especially if corporate trainers, higher educators, or anyone else is attempting to use a new vessel to deliver an old, outdated, “instructivist” pedagogical substance.

**Pedagogical Debates**

Wiley (2000) wrote that “There has been a movement in educational psychology against top-down, instructor designed facilitations in favor of scenarios where students actively engage in constructing their own knowl-
edge and meaning for themselves.” What Wiley noted was that constructivist learning techniques should be paired with peer-to-peer network technologies. His argument is not at first apparent, considering the efforts that have gone into creating “valuable” generic learning objects, which can be mixed and matched, “correctly assembled,” and distributed to learners in a variety of programmed learning paths, at the judgment of the instructional designer or instructor -

And therein lies our tie to constructivism. What if there is no correct assembly method? What if assembly per se is not involved in the utilization of learning objects at all? What if learning objects were treated as nodes in a massive distributed knowledge network? Assembly of objects according to designer-designed rules could be supplanted as the main mode of learning object utilization by learning object linking (creating new paths between network nodes) and annotating. And because the designer would not mandate the ways in which the learning objects will be assembled ahead of time, there is no requirement for standard grain sizes. The learner would collaborate with other learners (whether students, faculty, or other) to socially construct their own understanding through active collaborative knowledge construction.

Wiley further notes that the advantages of constructive interpretation of more raw learning objects are numerous. The need to process learning objects into standardized forms, let alone the need to argue what those standardized forms should be, goes away. The ability to use native material means that it is likely useful learning content in native formats would be available freely. Barriers to sharing and publication are reduced. The role of metadata is diminished, because in many domains it becomes self organizing, for example sharing music is facilitated by a scheme of the artist: song. Students and faculty already have large numbers of resources stored on their personal computers. This could allow critical user mass to be reached in a much shorter time frame, eliminating production delays and unfulfilled waiting hype. Holistic-level resources could function as an “incubator” from which exceptional resources could be elevated into more prestigious and ratified collections. In respect to the intellectual property question, however, Wiley’s answer is simplistic and naïve. He sees an ideal world where these resources are to be “saved” and are by their unrecognized nature, “free.” He does not realize that at some point a network of peers using resources in such a fashion needs to be bound by mutual agreement ahead of time. This argues against the likelihood of sustained success for a purely atomistic model.
In a later writing, Wiley and Edwards (2002), Wiley realized this. In his discussion at http://wwwslashdotorg he described (p. 7) how a hierarchy must emerge in any online self-organizing social system (OSOSS), whether it is a learning system or otherwise.

Again, then we see that forces mediate one another, and the most likely result is some kind of hybrid between a completely atomistic model and one which has some balance of distributed control. As O’Reilly (2001) summed up “Centralization and decentralization are never so clearly separable as anyone fixated on buzzwords might like.”

Educational Applications

Applications, which capitalize on some degree of peer-to-peer strategies are challenged with hiding the complexities of serving users beneath a simple interface. The interface model which is most instructive is the “two-way conversation,” which is a function currently available in the instant messaging platforms. Miller (2001) pointed out that the next extension of the functionality is to “conversations” between any combination of persons, applications, or devices. Jabber is a tool being developed with this in mind. It is set of codes which “enables software to have conversations in XML” (p. 84).

XML is not only the core format in for encoding data in Jabber; it is also the protocol, the transport layer between peers, the storage format, and the internal data model within most applications. XML permeates every conversation. (p. 84)

Another application (2002)which has gained much notice is Groove.

Groove Networks promote their platform for use in education by describing a number of functions and scenarios within which their platform’s functions would provide a superior solution than currently available using e-mail and web browsers. They state the functions as:

- fosters natural and constructive interaction through many media types—discussions, live/real-time voice, instant messages, drawings, video, and so forth;
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- provides users with direct control over the functionality and membership in a shared space;
- is appropriate for use with known acquaintances and colleagues, or can be extended to Groove users and communities that are unknown to a user before introduction; and
- allows access to content at all times, online and offline.

It is likely that both open source and commercial solutions applicable to P2P learning will continue to emerge. XML appears to be a major force. Applications, in addition to managing communications and resources between users, will meet the challenge of presenting users with a natural and contiguous communications experience, and will connect not only people, but applications and devices.

CONCLUSIONS

Implications for Management of Technology in Education

The arrival of P2P technologies, in the short-term, will not make life any easier for those tasked with managing networks and technologies to support learning, whether it is in higher education, K-12 education, or corporate sector human resource development.

Technology managers will need to keep abreast of these technologies and navigate through various emerging functionalities which continue to be loosely grouped under the heading of P2P. They should monitor, and where appropriate, follow the progress achieved by early adopters.

The likelihood of institutional pressures on educational technology managers to implement P2P technologies may depend on the instructional/constructivism orientation of a particular organization. Pressure will also appear at a holistic level, driven by the greater propensity to adopt new approaches from learner/users of institutions’ networks.

Pressures against anarchy, as well as the natural tendencies of systems to seek equilibrium (as illustrated at Slashdot.com), means that hybrid networking approaches will emerge. These hybrids will allow for some distributed functionality, alleviate bottlenecks, and allow for diverse user needs,
while maintaining hierarchical security and control over sensitive network operations and assets. One example of this is the Open Knowledge Initiative underway at MIT, where modularity is a key feature.

These offsetting pressures will likely move networking to new configurations, only as fast, if not a little faster, than the cultures of higher education, K-12, and corporate/governmental institutions are able to change and accommodate the new functionalities. In a few cases, however, the technology may be a driving force for cultural change, or new competing organization may use the technology to supercede existing institutions.

Wider developments in internet technologies, such as Internet2, bandwidth/compression factors, connectivity of devices, cross-platform usability of applications, security breakthroughs, and increasingly powerful users’ PCs will all strengthen arguments for adopting P2P networking strategies for educational objectives.

In summary, the alignment of technology and pedagogy is a complex objective. Both technology and pedagogy are in a state of flux, and different learning communities have differing orientations toward each. However, a synthesis of the factors and developments identified in this article indicates that “cost/benefit of change,” “instructional/learning utility,” and “organizational culture” (including instructional/constructivism orientation) are the most likely descriptors that will, in the nearer term, be charted under the growing “education bubble,” into the “meme of P2P.”

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