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Introduction: A Sea Change in Thinking, Knowing, Learning, and Teaching

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Forty years ago, Marshall McLuhan discussed how media at that time influenced both messages and users.¹ Today, we see a broader spectrum of more powerful information technologies (IT) providing a much wider range of capabilities for communication, entertainment, personal expression, and education. Studying how undergraduates use electronic devices to these ends—and in turn how they are actively and tacitly shaped by their media—provides insights on important aspects of students' cognition, motivation, self-image, and learning that can inform our designs for academic instruction and enculturation.

Our Tools Shape Our Communicating, Thinking, and Learning

Long ago, I wrote my doctoral dissertation on a typewriter, since word processors did not then exist. This was an agonizing process in which I spent a couple of minutes pondering the wording of each sentence, not setting it to paper until I felt confident, because I knew how difficult later changes would be. Inevitably, despite my best efforts at initial composition, I found myself struggling with whiteout and correction tape, cursing my inability to achieve perfection in a single intellectual leap.

Now, with word processing, I write in a completely different manner, setting down a sentence almost immediately, then rewording and reshuffling and reviewing until ultimately after many drafts I am satisfied. Writing as revision is a much better experience both intellectually (a higher-quality expressive product) and emotionally (no time lost to whitewashing the sepulchers of past suboptimal phrasings). However, as a cost of this advance, I find I cannot write fluently with paper and pencil anymore; because I am used to writing as revision, I wear out the eraser before I dull the point of the pencil!

Through modern media, my interactions with students and colleagues have changed in other ways. As I write, I am 2,000 miles from campus, yet I am providing individual advice to students via e-mail, responding just a few hours after they query me, without both of us having to find common time for a synchronous telephone conversation or face-to-face meeting—although of course I do these too, as needed. When we use “mediated” communication in moderation, the convenience, efficiency, and timeliness of interaction seem reasonable benefits to compensate for some loss of psychosocial presence. I don't know my students' faces as well, but I have a deeper, richer understanding of their needs and

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issues than I did before communication across distance was so facile.

Earlier this morning, I posted into an asynchronous threaded discussion I am having in one of my courses. I noted that students who are silent and passive in class sessions, despite my best efforts to draw them out, often “find their voices” in this medium—or in simultaneous virtual interactions for those who feel async is too slow for their communicative style. Also, in our online discussions students are more likely to respond to each other’s points and to contribute their own insights, rather than seeing me as the only source of knowledge in spite of my efforts to avoid the “sage on the stage” role. In addition, we increase our opportunities for sharing information and co-constructing meaning, since in class only one person at a time can speak during the limited number of hours we have available. Late in the semester, when each student reflects on what he or she has learned, examining the transcripts of these dialogues for evidence of intellectual evolution over the course of the semester is a very useful assessment of progress and accomplishment.

And yet, despite my pleasure in these advances in my instructional and advisory capacity, how superannuated this description seems to some of today’s undergraduates! Why bother with a word processor when one can create a rich multimedia representation on MySpace or YouTube? Why use e-mail when one can instant message? Why have a written dialogue as opposed to reciprocal blogging, or co-creating a wiki entry, or developing interrelated structures of tags on a social networking site? Why not have our avatars meet in an immersive virtual environment instead of co-locating in a physical classroom? For that matter, once we are in cyberspace, why not experience an immersive simulation together as opposed to just talking back and forth?

These questions illustrate that thus far faculty have typically used advances in IT either

to automate conventional forms of instruction or to make small steps in expanding the range of communicative and experiential patterns we accommodate. I am not belittling this progress; in my own instruction and research, the innovations I describe above are very useful. But we have just scratched the surface in examining the options emerging technologies offer for expanding the repertoire of ways we think and learn together.

We face a whole series of unknowns now in our instructional designs. As one illustration, for the purpose of negotiating shared meaning about a complex phenomenon, how do we determine the conditions under which one might want students to co-construct a wiki entry, rather than to have a virtual discussion or a face-to-face dialogue? Much research is needed to establish the complementary strengths and limits of the many types of media now in our instructional toolbox. One place to begin is using analytic methods like the ECAR surveys to examine the ways undergraduates use electronic devices throughout their lives, sifting out the dross of behaviors adopted just because they are novel and stylish from the ore of transformational approaches to creating, sharing, and mastering knowledge.

Beyond Automation to Transformation

The implications for institutions of higher education go well beyond the surface conclusion that students are using interactive media, so we had better use them too. To the extent that powerful engagement and learning, thinking styles, and new literacies are emerging from students’ usage, the academy should rethink how we view the creation, sharing, and mastery of knowledge. The findings from these ECAR surveys may be the initial tremors of larger tectonic shifts in the fundamental nature of research and instruction.

For example, wikis provide the opportunity for multiple participants to co-create

documents across distance. We know this capability is very useful in face-to-face collaborative learning, exemplified by such activities as design team members sketching simultaneously on a large, shared whiteboard, annotating each other's ideas. I know several academic research teams now using wikis very effectively to develop common terminology and shared meaning for the theoretical position the group is developing. As the curriculum standards championed by the Partnership for 21st Century Skills illustrate, the capability to provide virtual collaborative workspaces shared across distance is valuable not only for learning but also for preparing students to work in a global, knowledge-based economy.²

Another emerging technology likely to add significant value for learning is "sociosemantic networking." The many Web sites created early in the 21st century fueled efforts to categorize and organize the Web in order to empower users seeking "needles in haystacks." Google, Yahoo!, AOL, and others developed complex page ranking systems and algorithms to link information seekers to pertinent resources. Finding what one wanted on the Web became easier, but organizing and saving these resources was increasingly harder. Online communities clamored for intuitive ways to store and share their "gold mine" resources with friends and colleagues—enter the social bookmarking revolution.³

The years 2003–2004 marked the release of del.icio.us, Furl, Simpy, and Flickr, some of the more popular online social bookmarking communities. Instead of saving Web sites to their browsers and photos to their computers, individuals began saving bookmarks and photos online, sharing them with others and—most important—labeling the items with words they could remember. This bottom-up, participant-driven method of identifying bookmarks and photos with personalized keywords adopted the industry moniker "social tagging," and the process of

creating online, community-based meaning for content was born.

Due to their ability to quickly identify and adapt to changes in colloquial language, social tagging applications are of particular interest to instructors teaching introductory courses. When given access to complex, interlinked resources in a new subject domain, students' emergent language to describe what they are finding evolves faster than most faculty can follow. Social tagging affords students the ability to use their words to describe content and their words to search for content, as well as a tacit mechanism to articulate perceived relationships among content items. Seldow proposes that social tagging of files and Web pages within student communities is a direct and intuitive way to label and correlate ideas, easier for novices than the top-down, elaborate, nested hierarchies of prespecified, narrowly defined terms that characterize formal classification frameworks from the academic disciplines.⁴

Beyond providing vehicles for sharing resources, sociosemantic networking helps participants to develop evolving, collective knowledge structures that reflect interrelationships among tags. For faculty, these bottom-up depictions of conceptual frameworks may aid in diagnosing what students do and do not understand about the ideas presented in courses and degree programs. Faculty may also gain insights about how to teach material from the bottom-up vocabulary and systemic interconnections that emerge through students' collective tagging. With a grant from Harvard's provost, my colleagues and I are studying how an academic social networking tool we have designed (<http://www.edtags.org>) aggregates tags across a broad community. This type of electronic resource may help entire degree programs improve cross-course instruction that goes beyond individual faculty insights from the subset of students in each particular course.

New Interfaces, “Neomillennial” Learning Styles, and Novel Literacies

At a deeper level, three complementary technological interfaces are now shaping how people learn, with multiple implications for higher education:

- ◆ The familiar “world-to-the-desktop” interface provides access to distributed knowledge and expertise across space and time through networked media.
- ◆ Multiuser virtual environment (MUVE) interfaces offer students an engaging “Alice in Wonderland” experience in which their digital emissaries in a graphical virtual context actively engage in experiences with the avatars of other participants and with computerized agents. MUVEs provide rich environments in which participants interact with digital objects and tools, such as historical photographs or virtual microscopes. Moreover, this interface facilitates novel forms of communication among avatars, using media such as text chat and virtual gestures.⁵
- ◆ Augmented reality (AR) interfaces enable “ubiquitous computing” models. Students carrying mobile wireless devices through real-world contexts engage with virtual information superimposed on physical landscapes (such as a tree describing its botanical characteristics or a historic photograph offering a contrast with the present scene). This type of mediated immersion infuses digital resources throughout the real world, augmenting students’ experiences and interactions.⁶

My colleagues and I are studying how immersion in virtual environments and augmented realities shapes participants’ learning styles, strengths, and preferences in new ways beyond what using sophisticated

computers and telecommunications has generated thus far, with many potential consequences for the academy. One of my advanced doctoral students, Ed Dieterle, describes in his dissertation proposal how the “styles” by which people think and act and learn are theoretical constructs designed to help explain these processes: complex patterns shaped by physical and mental development, personal interests, and sociocultural influences.⁷

Scholarly ruminations on styles are disparate and complex, encompassing “cognitive style, conceptual tempo, decision-making and problem-solving style, learning style, mind style, perceptual style, and thinking style.”⁸ Learning styles, as Keefe explains, are a composite of cognitive styles, which consider concept formation and retention and sensory reception; affective styles, which consider attention, expectancy, and incentive; and physiological styles, which consider the functions and activities, including all physical and chemical processes, of human organisms.⁹ The cognitive component of learning styles is synonymous with thinking styles; in general, these characterize “how one prefers to think about material as one is learning it or after one already knows it.”¹⁰

In my research, I have described the types of learning strengths, styles, and preferences that “neomillennial” students acquire from their use of immersive collaborative media, such as multiplayer online games.¹¹ These include

- ◆ fluency in multiple media, valuing each for the types of communication, activities, experiences, and expressions it empowers;
- ◆ learning based on collectively seeking, sieving, and synthesizing experiences, rather than individually locating and absorbing information from some single best source;
- ◆ active learning based on experience (real and simulated) that includes frequent opportunities for reflection;

- ◆ expression through nonlinear, associational webs of representations rather than linear “stories” (for example, authoring a simulation and a Web page rather than a paper to express understanding); and
- ◆ codesign of learning experiences personalized to individual needs and preferences.

Ed Dieterle’s dissertation research is studying whether using immersive collaborative simulations in classroom settings offers a powerful method for building on these learning strengths and preferences to nurture 21st-century understandings and performances.¹²

Rather than learning styles, Jenkins and his colleagues delineate a set of novel literacies based on usage of new media:

- ◆ play, the capacity to experiment with one’s surroundings as a form of problem solving;
- ◆ performance, the ability to adopt alternative identities for the purpose of improvisation and discovery;
- ◆ simulation, the ability to interpret and construct dynamic models of real-world processes;
- ◆ appropriation, the ability to meaningfully sample and remix media content;
- ◆ multitasking, the ability to scan one’s environment and shift focus as needed to salient details;
- ◆ distributed cognition, the ability to interact meaningfully with tools that expand mental capacities;
- ◆ collective intelligence, the ability to pool knowledge and compare notes with others toward a common goal;
- ◆ judgment, the ability to evaluate the reliability and credibility of different information sources;
- ◆ transmedia navigation, the ability to follow the flow of stories and information across multiple modalities;
- ◆ networking, the ability to search for,

synthesize, and disseminate information; and

- ◆ negotiation, the ability to travel across diverse communities, discerning and respecting multiple perspectives, and grasping and following alternative norms.¹³

Students who develop these literacies via their activities in communication, entertainment, and personal expression outside academic settings may well push for—and benefit from—instruction that builds on these capabilities.

Leu and his colleagues describe four characteristics of these “new literacies” generated by information technologies. First, emerging computer-based tools, applications, media, and environments require novel skills, strategies, and dispositions for their effective use. Second, new literacies are central to full economic, civic, and personal participation in a globalized society. Third, new literacies constantly evolve as their defining information and communication technologies (ICT) are renewed continuously through innovation. Fourth, new literacies are multiple, multimodal, and multifaceted. These characteristics are in accord with the media-based styles of learning presented above.¹⁴

Leu’s third point raises important issues about stability: How durable are these literacies in their applicability to 21st-century work, citizenship, and self-actualization? How quickly will additional, important learning styles emerge as computers and telecommunications continue to evolve? Certainly tools, applications, media, and environments are changing rapidly, with no end in sight. Typically, despite predictions of paperless offices or the end of the book, this evolution involves adding new literacies and thinking styles rather than new capabilities undercutting the value of older skills. Hence the value of longitudinal usage data, as collected in these ECAR surveys.

Throwing Gasoline on the Fire

In recent years, the National Science Foundation (NSF) has championed a vision of the future of research that centers on “cyberinfrastructure”—the integration of computing, data and networks, digitally enabled sensors, observatories and experimental facilities, and an interoperable suite of software and middleware services and tools.¹⁵ Gains in computational speed, high-bandwidth networking, software development, databases, visualization tools, and collaboration platforms are reshaping the practices of scholarship and beginning to transform teaching.¹⁶ Cyberinfrastructures developed for research purposes also create intriguing opportunities to transform education, in part by infusing research into teaching and in part by adapting powerful mechanisms for “mediated” knowledge creation and sharing in scholarly communities to teaching and learning in course settings.

During 2004–2005, with NSF funding, the Computing Research Association convened four workshops attended by experts in education. These workshops focused on

- ◆ modeling, simulation, and gaming technologies applied to education;
- ◆ cognitive implications of virtual or Web-enabled environments;
- ◆ how emerging technology and cyberinfrastructure might revolutionize the role of assessment in learning; and
- ◆ the interplay between communities of learning or practice and cyberinfrastructure.

Collectively, these groups envisioned a cyberinfrastructure that “provides: 1) unprecedented access to educational resources, mentors, experts, and online educational activities and virtual environments; 2) timely, accurate assessment of student learning; and 3) a platform for large-scale research on education and the sciences of learning. Moreover, the new educational cyberin-

frastructure will make it possible to collect and analyze data continually from millions of educational activities nationwide over a period of years, enabling new advances in the sciences of learning and providing systematic ways of measuring progress at all levels.”¹⁷

The NSF Cyberinfrastructure Council provides a scenario of how advanced visualization and simulation capabilities could advance education.¹⁸ Imagine an interdisciplinary course in the design and construction of large public works projects, attracting student–faculty teams from different engineering disciplines, urban planning, environmental science, and economics, and from around the globe. To develop their understanding, the students combine relatively small, self-contained digital simulations that capture both simple behavior and geometry to model more complex scientific and engineering phenomena. Modules share inputs and outputs and otherwise interoperate. These “building blocks” maintain sensitivity across multiple scales of phenomena.

For example, component models of transportation subsystems from one site combine with structural and geotechnical models from other collections to simulate dynamic loading within a complex bridge and tunnel environment. Computational models from faculty research efforts are used to generate numerical data sets for comparison with data from physical observations of real transportation systems obtained from various (international) locations via access to remote instrumentation. Learners can also explore influences on air quality and tap into the expertise of practicing environmental scientists through either real-time or asynchronous communication. This networked learning environment increases the impact and accessibility of all resources by allowing students to search for and discover content, assemble curricular and learning modules from component pieces in a flexible manner, and communicate and

collaborate with others, leading to a deep change in the relationship between students and knowledge. Indeed, students experience the profound changes in the practice of science and engineering and the nature of inquiry that cyberinfrastructure provokes.

One could create comparable vignettes to illustrate educational opportunities in constellations of fields across the sciences and social sciences. Overall, cyberinfrastructure investments will add momentum to attempts to infuse emerging media into college and university teaching.

Conclusion

In Shakespeare's *The Tempest*, Ariel sings to Ferdinand:

*Full fathom five thy father lies;
Of his bones are coral made;
Those are pearls that were his
eyes:
Nothing of him that doth fade
But doth suffer a sea-change
Into something rich and strange.*

Our ways of thinking and knowing, teaching and learning are undergoing a sea change, and what is emerging seems both rich and strange. The rising tide of sophisticated information and communications technologies driving this shift will not recede, so we should try to understand the richness, to welcome the strangeness as a source of creative insight, and to fuse some synthesis combining the best of old and new. A dialogue with students, including both advocates and critics, around these survey findings is a first step toward such a goal. Another important step is sharing the results of the many small experiments instructors are individually conducting to explore the strengths and limits of emerging interactive media.

Many faculty view the shifts I describe above with deep suspicion. They fear that teaching and learning will end up as Ariel portrays Ferdinand's father to be: rich, strange, and lifeless. I have colleagues who

hope to retire before the sea change forces them to confront the prospect that, as in other professions, the old ways are no longer best. Yet many more of us welcome the opportunity for renewal that advanced information and communications technologies offer and hope to serve a vital role in their development, tempering the new vistas they offer with wisdom and experience based on the strengths and limits of older educational media. Whatever one's stance—concern or hope—the results of these ECAR surveys offer much food for thought.

Endnotes

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