Design Research Exploring Transformative Frameworks for Learning and Education

AERA Invited Presidential Address

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Abstract

Learning and education are experiencing a period of profound transformation. Phenomena such as *globalization*, increasing trends to *outsource high-level cognitive tasks*, and the need to participate effectively in addressing *complex world problems* are changing how we think, learn, work, and collaborate. These challenges create new educational demands: students need to be educated for a diverse, technical, problem-oriented world that does not yet exist. It is imperative that students become self-directed, lifelong learners who can thrive and participate in collaborative environments with ever-changing disciplinary boundaries.

New technologies create learning opportunities that challenge traditional schools and colleges by creating new learning niches that enable people of all ages to pursue learning on their own terms, pursuing their particular goals and interests, and taking responsibility for their own learning. Fostering this kind of long tail inspired, rather than curriculum driven learning requires a rethinking of education. This symposium will explore the articulation, design, and assessment of innovative conceptual frameworks, new learning environments and new learning organizations to foster the social imagination of all stakeholders.

Objectives

"Philosophers interpret the world in various ways;
what matters is to change it!" — Karl Marx

Following Karl Popper's argumentation, we subscribe to his basic assumption that new and deeper understanding does not start with perceptions, observations, or collections of data — but it starts with problems. Our shared research agenda is grounded in "doing basic research on real problems". Some of the basic assumptions underlying our shared research agenda are:

- school is a designed artifact (and not a immutable organization shaped by nature [Simon, 1996]) whose role needs to be reconsidered in the 21st century (as articulated by Illich 40 years ago in his vision for learning webs [Illich, 1971]): *"The current search for new educational funnels must be reversed into the search for their institutional inverse: educational webs which heighten the opportunity for each one to transform each moment of his living into one of learning, sharing, and caring");*
- *informal learning* should complement formal learning [Bransford et al., 2006];
- education research and environments should not be restricted to "learning when the answer is known" but should support "collaborative knowledge construction in real world problems when no one knows the answer" [Engeström & Sannino, 2010];

- the role of teacher and learner that was historically associated with a person should be associated with a *context* [Rogoff et al., 1998];
- *passion-based learning* (based on learners idiosyncratic interests) should be exploited, supported, and serve as anchor points for standard curriculum units [Collins & Halverson, 2009].

Media and technologies can and should serve as extensions of humans [McLuhan, 1964]. The history of the human race is one of ever-increasing intellectual capability: our brains have gotten no bigger and our hands no more skilled or stronger, but there has been a continuous accumulation of new tools for physical and intellectual work.

Short Description of Individual Presentations

In our research we have argued that many advanced learning technology approaches are *too timid* and are *not thinking radically enough* for the following reasons [Fischer, 2007]:

- *accepting too many established approaches*—e.g.: a theory of human learning based solely on school learning is too limited but the success of universal schooling has led us to identify learning with schooling [Collins & Halverson, 2009; Illich, 1971];
- *not embracing new learning opportunities*—e.g.: exploiting the unique opportunities of social production in which all learners can act as active contributors in personally meaningful problems [Benkler, 2006; Resnick, 2007];
- *reducing digital literacy and fluency* to accessing and comprehending existing information rather than empowering learners to reformulate knowledge, to express themselves creatively and appropriately, and to produce and generate information [Brown & Adler, 2008]; and
- *not moving beyond "gift-wrapping" and "techno-determinism"* to the co-evolution of learning, new media, and new learning organizations [Fischer, 1998].

Cultures of Participation, Long Tail Learning, and Energy Sustainability

Gerhard Fischer, University of Colorado at Boulder

Cultures of Participation. The first decade of the World Wide Web enforced a clear separation between designers and consumers, but new technological developments, such as the cyberinfrastructure and Web 2.0 architectures, have emerged to support a social or participatory Web. These developments are the foundations for a fundamental shift from a *consumer culture* (in which people passively consume finished goods produced by others) to a *culture of participation* (in which all people are provided with the means to participate actively in personally meaningful activities). Innovative technological developments are *necessary* for cultures of participation, but they are *not sufficient*. The deep and enduring changes are not just technological, but social and cultural requiring socio-technical systems are necessary. Cultures of participation are the result of incremental shifts in human behavior and social organizations, including design, adoption, appropriation, and adaptation of technologies to the needs of the participants. They offer opportunities for collaborative knowledge construction, peer-to-peer learning, development of skills and mindsets relevant throughout life, and more empowered levels of engagement for the public good [Jenkins, 2009].

A Long-Tail Interpretation for Interest-Driven and Passion-Based Learning. The *Long Tail theory* [Anderson, 2006] postulates that our culture and economy is increasingly shifting away from a focus on a relatively small number of "hits" (mainstream products and markets) at the head of the demand curve and toward a huge number of niches in the tail. Information technologies have greatly enhanced the ability to take advantage of the Long Tail by exploiting niche markets and connecting people with communities and products of interest. We have been exploring the implications of the Long Tail theory for *learning and education* [Collins et al., 2009] by focusing on two of its transformational aspects: (1) learning about exotic topics outside the mainstream education curriculum, and (2) the opportunity to communicate with people who share similar interests somewhere in the world on a regular basis. The web (specifically the Web 2.0 supporting cultures of participation) gives children and adults the ability to pursue topics they are particularly interested and feel passionate about. These are topics learners never encounter in school unless they pursue them later in college.

Schools, however, have moved in the opposite direction. Even as computers become more ubiquitous in schools, curriculum standards and mandated assessments (based on frameworks such as cultural literacy [Hirsch, 1996]) have exercised a conservative force against the proliferation of idiosyncratic interests and passion by emphasizing that everyone should learn the same thing at the same time, as measured by the same standards. Similarly, the education establishment has tried to control what people learn by defining the curriculum in schools. The dramatically increasing amount of non-mainstream knowledge indicates a gap between the world we live in and the formal education, where the latter focuses mainly on limited amount of knowledge.

Some questions to be explored, discussed, and debated in this presidential address are:

- How can the passion associated with topics from the tail be integrated with important basic knowledge and skills from the head that they successfully complement each other?
- Do we want to keep requiring everyone to learn the same thing in school rather than pursuing their deep interests?
- Do we want to support kids to pursue more deeply the topics of interest to them — and if so, how?
- How does access to tools and learning resources influence long tail learning?

Energy Sustainability: Engagement for the Public Good. We are exploring the conceptual frameworks of cultures of participation and long-tail inspired learning in the context of energy sustainability, a theme of national and worldwide importance. Every aspect of our lives relies on energy, and societies as a whole are affected by the energy behavior of its citizens. The development of a more responsible use of energy is one of the most important goals in our society. The challenges of harvesting the benefits of technical innovations such as the *Smart Grid* (overlaying the electrical grid with a computational information system facilitating two-way communication) and *advanced metering infrastructure*s (measuring, collecting, and analyzing energy usage by interacting with smart meter devices) are numerous: (1) most citizens are unaware of new technological developments; (2) information presentation is poorly designed; (3) the social context of individual energy use is ignored, and few interaction and collaboration mechanisms exist; and (4) feedback alone is not persuasive enough to change human behavior. All of these challenges are grounded in the intersection of human behavior (at the individual and social levels) and technology.

Scientific Literacy in the Context of Civic Reasoning: An Educational Design Problem

Sharon Derry, University of Wisconsin-Madison and Daniel Zalles, SRI International

Collective Citizenship: A Top Priority. 21st century cyber infrastructures for distributed learning, communication, and knowledge sharing are unprecedented in the opportunities they provide for global citizens to come together to address the critical problems facing our world. Yet as recent events illustrate, these same technologies may also serve as powerfully destructive tools. We argue, therefore, that *active, collective citizenship through responsible civic reasoning, empowered by tools of science and technology, is the overarching educational goal of our time.* Although few in our audience are likely to disagree, many may feel we are unable to reach this goal. They might point, for example, to disturbing recent statistics such as a finding (reported in [Michigan State University, 2007]) that 70 percent of all U.S. adults struggle to read and understand the science section of the New York Times.

Connect Science with Civic Reasoning. Standards and institutions that break education into discrete disciplinary components create additional stumbling blocks. To help illustrate this point, we offer a model consisting of six interacting phases of civic reasoning that characterize the way a socio-technical community can take action on issues having scientific aspects.

- Seeking common ground and consensus on what constitutes problems and needs.
- Leveraging power structures to fund and support important avenues of work.
- Designing and conducting research.
- Participating in peer review through communities of practice.
- Setting policy or taking action based on policy.
- Evaluating policy effectiveness.

National and state science standards are about accumulating canonical scientific knowledge and designing and carrying out discipline-appropriate scientific research, with some attention to persuasively communicating and critiquing results. These are the goals of only phase 3 and, to some extent, phase 4. Such focus provides a myopic view of a world in which scientists are merely specialized citizens immersed with everyone else in the broad struggle to improve the world.

Educational Designs for Civic Reasoning. Citing examples from our own work and that of others, we will illustrate cases *of* and argue the case *for* interdisciplinary educational design based on a full model of civic reasoning in technology-rich environments. Such designs enhance broad understanding of scientific, social, economic, and cultural aspects of issues. In addition, they increase students' abilities to engage more productively and effectively with issues through reflection and meta-cognition, productive discourse, and study of challenges in advancing issue-related knowledge and evaluating effects of issue-related policies and other actions.

Mind and Hand, Re-introduced: or Educational Technology in the Physical World

Michael Eisenberg, University of Colorado, Boulder

Traditionally, the term "educational technology" has been implicitly equated with "computers in schools". This interpretation is mistaken. Technology is much more than computing, and education is far too complex and pervasive to be equated with a classroom setting alone. Educational technology is now undergoing a revolution–or what might better be called several convergent revolutions–that, in combination, call into question our historical assumptions about the role of technology in children's lives.

One of the most prominent changes in educational technology is reflected in the increasing integration between computation and physical materials. This integration takes a variety of forms:

- **Physical materials**–paper, textile, ceramics–can now be endowed with computational behaviors by the inclusion of small, inexpensive kits of processors, sensors, and actuators. This notion of "material computing" allows children to create new types of constructions–responsive clothing, or papercrafts, or clay sculptures. The landscape of traditional materials and craft activities available to children is thus about to undergo a tremendous expansion.
- **Fabrication tools and devices**–paper cutters, laser cutters, 3D printers, computer-controlled sewing machines, and many others–now permit children to create highly accurate, complex, expressive, and aesthetically appealing creations in a variety of physical materials (including, for example, wood, acrylic, textile, paper, and wax). In essence, this is a sea change in the traditional notion of "shop": the nature and possibilities of children's construction are vastly different from what they were a generation ago.
- An **expanding ecosystem of computational tools, materials, devices, and infrastructure** is now taking shape to support and extend the developments mentioned above. New physical materials (conductive paints, glues, threads) support the integration of computing within tangible objects. Devices such as 3D scanners, nanoprojectors, and RFID readers (to name just a few) can be creatively combined with tangible computing. Websites and social networks can be recruited in the service of new models of physical construction.

Collectively, these developments portend a redefinition of educational technology, and a breakdown of educational divisions that are increasingly recognized as arbitrary: between "knowledge work" and "manual work", between "liberal arts" and "vocational" education, between "formal" and "informal" settings for learning. This presentation will demonstrate a variety of projects from our lab that highlight these new directions in educational technology. In particular, we will demonstrate examples of notions such as *material computing*, *ambient programming*, *children's fabrication tools*, and *programming on novel surfaces*.

Social Computational Thinking Tools

Alexander Repenning, University of Colorado at Boulder

For the last 15 years we have been exploring notions of design and social media as means to foster highly engaging as well as effective educational environments. We have created what we call *social computational thinking tools* with the goal to synthesize *human abilities* with *computer affordances* in a Yin and Yang kind of way. Our approach to broaden participation has been to design, develop, evaluate and disseminate these tools in K-12 setting to make them benefit the Public Good. Exploring ecologies of students, teachers, and facilitators we have been able to create curricula usable by a surprisingly broad range of users. This presentation will outline three social computational thinking tools and discuss how they have combined notions of design and social media to create unique learning experiences in the classroom.

- ***Collective Simulation***: Mr. Vetro, a Human Physiology exploration. Interactive simulations appear to hold great educational power especially to explore complex systems such as human physiology through a process of inquiry. Unfortunately, simulations in the classroom have not quite lived up to their full potential largely because of the way they are used. Imagine a large class situated in a computer lab with each student manipulating a simulation of a human on a computer. Economic factors aside, it is not clear what the benefits, pedagogical or otherwise, of multiple students sharing physical space in a class room even are. Collective simulations reconceptualize the role of students, technology and the teacher in the classroom by engaging all participants in a social role-play. Mr. Vetro is an example of a physiological collective simulation in which each student plays, facilitated through a handheld computer, the role of an organ. At the individual level a student may play the role of the heart, the lung, or some other organ. If students need to control other parts of the simulation they have to engage in scientific discourse by arguing *why* that other organ should engage in some change. Through a wireless network all the students with their simulated organs are connected to a bigger whole called Mr. Vetro. At this social level all the students experience the consequences of their local decisions. The teacher is a facilitator managing an activity and moderating between organs. The results of this research is highly encouraging by indicating the ability to still be able to perform at better or equal levels at standardized tests but, through larger degrees of engagement, develop deeper knowledge and retention [Ioannidou, 2010].
- ***Scalable Game Design*** is a scalable, elementary to graduate school, game design curriculum. The most urgent goal of this project is to bring computer science education into public schools [Repenning, 2009] and to broadening participation by embedding the curriculum in required courses starting at the middle school level. To explore notions of equity Scalable Game Design investigates computer science education in different communities including inner city schools, remote rural areas and Native American communities. Starting with game design, and gradually moving towards science simulations, the approach taken carefully balances motivational and educational concerns of computer science education. Over many years, with AgentSheets, we have pioneered new approaches making programming substantially more accessible to students as well as to teachers through social interfaces [Repenning 1996]. Moreover, we have developed new kinds of research instruments allowing us to analyze computation-thinking pattern and to explore transfer from game design to computational science simulations [Koh 2010]. These means to measure computational thinking patterns are crucial to develop new kinds of cyberlearning technologies supporting individual and social levels of adaptive learning. With an average participation of over 50% girls and the majority of participants wanting to continue, the project has quickly grown beyond its initial scope by including schools and even entire school districts in Alaska, California, Wyoming, South Dakota, Colorado, and Texas.
- ***Collective Programming.*** CyberCollage, our most recent investigation joining notions of design with social media, is a cloud-based authoring approach in which any number of students can participate on projects in real time. For instance, imagine a joint project of two, or more, students working on a Frogger (a 1981 arcade style game) like game together in real time. The game becomes a shared collection of game assets such as art and programming components being developed collaboratively. Students can see what

other students are doing, if they so choose, or can pursue their own activities while keeping activities of others in a peripheral view. The ability to collaborate in this kind of way not only becomes an efficient means to tackle large projects but also becomes a powerful resource for peer based collaborative learning and social creativity.

Discussant

Allan Collins, Northwestern University, will review and discuss these contributions from the frameworks articulated in his book "*Rethinking Education in the Age of Technology: The Digital Revolution and Schooling in America"* [Collins & Halverson, 2009].

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