

META-DESIGN: EMPOWERING ALL STAKEHOLDER AS CO-DESIGNERS

Gerhard Fischer
Center for LifeLong Learning and Design (L3D)
University of Colorado Boulder, CO 80309-0430 USA
gerhard@colorado.edu

ABSTRACT

The design of educational technologies has been focused primarily on formal learning in schools supporting a transmission model based on learning “when the answer is known”. In doing so, many opportunities are missed in fostering and supporting learning in very different contexts, including lifelong learning, informal learning, and self-directed learning.

Meta-design is a theoretical framework empowering all stakeholders to participate, contribute and share content, provide feedback, and it is applicable to learning “when the answer is not known”. It empowers all learners to act as *co-designers in personally meaningful problems* and supports *cultures of participation* in which all voices are heard. This chapter discusses the impact of meta-design for transformative approaches to learning and education.

1. INTRODUCTION

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. New knowledge and skills for students in entering work environments require collaborations with experts from multiple fields, the pursuit of several career paths, and interacting and working with people of diverse backgrounds. These changes create new educational demands: learners need to be educated for a diverse, technical, problem-oriented world that does not yet exist. Meta-design represents a theoretical framework, supported by innovative information and communication technologies, in which learners of all ages can pursue topics of interest and take responsibility for their own education by empowering them to thrive and participate as co-designers in collaborative environments with ever-changing disciplinary boundaries.

2. FUNDAMENTAL TRANSFORMATIONS

New information and communication technologies (specifically the Internet and the cyberinfrastructure) have been heralded as the major driving forces behind

innovation in learning and education. But many approaches have had only a minor impact based on the following limitations:

- *Technology-centered developments*: Technology alone does not determine social structure: it creates feasibility spaces for new social and cultural practice [Benkler, 2006]. Changes in complex learning environments are not only dictated by technology; rather, they are the result of an incremental shift in human behavior and social organization and as such require the *co-design of social and technical systems*.
- *Gift-wrapping*: Many uses of new media can be characterized as “*gift-wrapping*”: they are used as add-ons to existing practices rather than a catalyst for fundamentally rethinking what education should and can be in the next century [Fischer, 1998]. They change the medium, but leave the content unchanged and contribute little to introducing new epistemologies. *Old* frameworks, such as instructionism, fixed curricula, memorization, decontextualized learning and so forth, are not changed by technology itself. This is true whether we use computer-based training, intelligent tutoring systems, multimedia presentations, or the World Wide Web.

Computational environments are needed to support *new* frameworks for education such as lifelong learning, integration of working and learning, learning on demand, self-directed learning, collaborative learning, and organizational learning [Fischer & Sugimoto, 2006]. To overcome these limitations, fundamental transformations need to be grounded in the *co-evolution* of (1) a new science of learning, (2) technological innovations embedded in socio-technical environments, and (3) new learning organizations supporting formal and informal learning.

How Things Are. The current emphasis on learning is focused on formal learning taking place in schools. It is based on instructionist models in which “*omniscient teachers tell or show presumably unknowing learners something they presumably know nothing about*” [Bruner, 1996]. Learning follows prescribed paths defined by curricula. It is conceptualized as “learning when the answer is known” grounded in a transmission model in which the learners should learn what the teachers know.

How Things Could Be. A science of learning for the 21st century needs to explore many types of learning other than traditional curriculum-based classroom learning. It must conceptualize learning as an inclusive, social, informal, participatory, and creative lifelong activity. The learning goals and the content of the learning activity should not only be determined by curricula but by interest-based, self-directed learning objectives. Many problems (specifically design problems) are unique and ill-defined and the knowledge to address them is not “out there” requiring contributions and ideas from all involved stakeholders. Learners in such settings must be *active contributors* rather than passive

consumers and the learning environments and learning organizations must foster and support mindsets, tools and skills that help learners become empowered and willing to actively contribute [Fischer, 2002].

Providing learners of all ages with the means to become co-creators of new ideas, knowledge, and products in personally meaningful activities presents one of the most exciting innovations and transformations of digital media, with profound implications in the years to come. Beyond supporting contributions from individuals, learning organizations need to build a culture and mindset of sharing, supported by effective technologies and sustained by personal motivation to work for the benefit of groups and communities. *Learning Webs* (as articulated by Illich 25 years before the Internet came into existence [Illich, 1971]) represent an early vision of such an environment based on two objectives: (1) provide all who want to learn with access to available resources at any time in their lives; and (2) empower all who want to share what they know to find those who want to learn it from them.

The following sections will explore meta-design as a design methodology to create new learning ecologies and environments to support these objectives. Meta-design supports fluency with IT and it is instrumental for “*the ability to reformulate knowledge, to express oneself creatively and appropriately, and to produce and generate information rather than simply to comprehend it*” [National-Research-Council, 1999]. It appeals to a diverse audience to engage in interest-driven, self-directed learning by supporting them in designing and building their own socio-technical environments by situating computation in new contexts and by developing tools that democratize design, innovation, and knowledge creation.

3. META-DESIGN

A Characterization of Meta-Design. Meta-design is a theoretical framework to conceptualize and to cope in unique ways with design problems. *Design* is a ubiquitous activity that is practiced in everyday life as well as in the workplace by professionals [Schön, 1983; Simon, 1996]. It is not restricted to any specific discipline, such as art or architecture, but instead is a broad human activity that pursues the question of “*how things ought to be*”, as compared to the natural sciences which study “*how things are*” [Simon, 1996]. It is a fundamental activity within all professions: (1) architects and urban planners design buildings and towns [Rittel, 1984]; (2) people in the creative practices design new artifacts with new media [National-Research-Council, 2003]; (3) citizens from around the world engage in cultures of participation [Fischer, 2011; Jenkins, 2009]; and (4) learning scientists in collaboration with media developers design innovative environments to support new learning activities and ecologies [Bruner, 1996; Collins & Halverson, 2009].

In a world that is not predictable, improvisation, evolution, and innovation are more than luxuries — they are *necessities*. The challenge of design is not a matter of getting rid of the emergent, but rather of including it and making it an opportunity for more creative and more adequate solutions to problems. Many design approaches force all the design intelligence to the earliest part of the design process, when everyone knows the least about what is really needed. Meta-design provides the enabling conditions for putting owners of problems in charge who act until they experience a breakdown that may lead them to reflection and learning new relevant topics on demand [Schön, 1983]. These breakdowns are experienced by end users and not by system builders. End users need the ability to evolve and refine their problem framing and solving attempts without relying on “high-tech scribes”. End-user modifiable systems extend the traditional notion of system design beyond the original development of a system to include an ongoing process in which the users of the system become *co-designers*. Meta-designers use their own creativity to produce socio-technical environments in which other people can be creative. They define the *technical* and *social* conditions for broad participation in design activities.

Meta-design is more than a technical problem: it addresses the challenges of fostering new mindsets, new sources of creativity, cultural changes, and innovative societies. It has the potential to create a culture in which all participants in collaborative design processes can express themselves and engage in personally meaningful activities [Engeström & Sannino, 2010].

Complementing Existing Design Methodologies. To explore the unique aspects of meta-design, it can be contrasted with a number of existing design methodologies:

- *Professionally-dominated design* [Rittel, 1984] (serving as the foundation of teacher- and curriculum-driven education [Rogoff et al., 1998]) represents a design methodology founded on the belief that professional experts understand the users’ needs. At design time, they create artifacts with which users “have to live with” at use time. While professionally-dominated design has its place, it often creates systems that are at odds with users’ interests, needs, and background knowledge.
- *User-centered design* [Norman & Draper, 1986] has been a major step forward to transcend the limitations of professional-dominated design by analysing the interests, needs, and background knowledge of users and envisioning how users are likely to use an artifact.
- *Learner-centered design* [Luckin, 2010] draws attention to the changing needs of users and it combines interaction principles with educational support for scaffolding and tailoring information and tools to the evolving background knowledge of the learner.

- *Participatory design* [Schuler & Namioka, 1993] seeks to involve users more deeply in the process as co-designers by empowering them to propose and generate design alternatives themselves. It requires the social inclusion and active participation of the users at *design time* by bringing developers and users together to envision the contexts of use.

Different from these approaches, meta-design creates *open systems* that can be modified by their users and evolved at *use time*. Open systems allow significant modifications when the need arises because despite the best efforts at design time, systems need to be evolvable to fit new needs and account for changing tasks.

Supporting Meta-Design with the Seeding, Evolutionary Growth, and Reseeding (SER) Model. The *SER model* [Fischer & Ostwald, 2002] is a descriptive and prescriptive model for creating systems that best fit an emerging and evolving context. Instead of attempting to build complete systems, the SER model advocates building *seeds* that can evolve over time. It postulates that systems that evolve over a sustained time span must continually alternate between (1) periods of planned activity and unplanned evolution, and (2) periods of deliberate (re)structuring and enhancement. A seed is something that has the potential to change and grow. In socio-technical environments, seeds need to be designed and created for the technical as well as the social component of the environment.

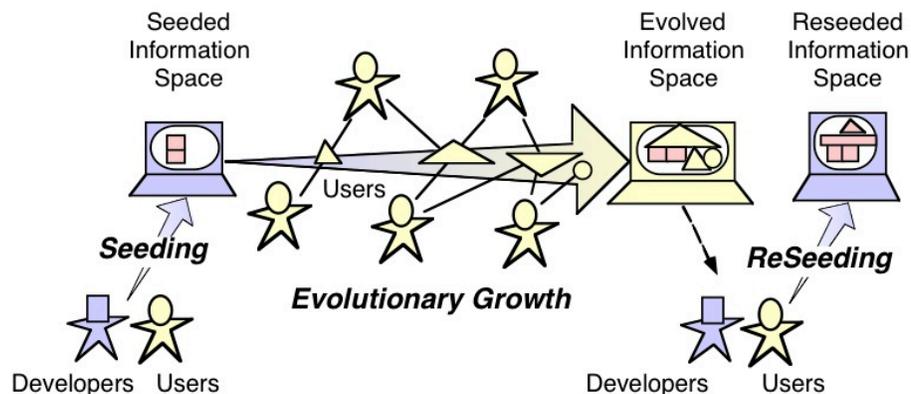


Figure 3.1: The Seeding, Evolutionary Growth, Reseeding (SER) Model

As illustrated in Figure 3.1, a *seed* is built based on an initial understanding and framing of a problem. It is created by meta-designers acting as environment developers for future users to be as complete as possible. However, the understanding of a problem cannot be complete due to the situated and tacit nature of knowledge work [Winograd & Flores, 1986]. Furthermore, the constant changes occurring in the environment in which systems are embedded will breed new needs, and the introduction of computational systems themselves generates changes in professional practices and socio-technical environments. Therefore,

the initial seed needs to be continuously adapted to the new understanding and new environments.

The *evolutionary growth* phase is one of decentralized evolution as the seed is used and extended by users to do their work or explore new problems. In this phase, the original developers are not directly involved because the focus has shifted to the problem framing and problem solving activities of the users. Instead, the development is performed by participants who have a direct stake in the problem at hand [von Hippel, 2005]. During the evolutionary growth phase, users focus on solving a specific problem and creating problem-specific solutions rather than on creating general solutions. As a result, the solutions added during this phase may not be well integrated with the rest of the solution in the seed.

Reseeding is a deliberate and centralized effort to organize, formalize, and generalize solutions and artifacts created during the evolutionary growth phase. The goal of reseeded is to create an information space in which useful solutions can be easily found, reused, and extended. As in the seeding phase, developers are needed to perform substantial system and solution space modifications and users must participate because only they can judge what solutions are useful and what structures will serve their work practices.

Different Models for Knowledge Creation, Accumulation, and Sharing. The process of knowledge creation, accumulation, and sharing in society has undergone major changes. Initially, knowledge was accumulated in the minds of people and communicated by tales, stories, and myths. The oral tradition has been replaced by a written tradition that allows people to permanently record thoughts and widely distribute them [Ong, 1982]. Information and communication technologies have created fundamentally new opportunities including the latest shift from consumer cultures to *cultures of participation* [Fischer, 2011]. Two models will be briefly described indicating approaches are preferable in different settings. Rather than being mutually exclusive, these models can complement each other.

MODEL-AUTHORITATIVE (see Figure 3.2) underlies *professionally dominated cultures* that are characterized by (1) a small number of experts (such as teachers) acting as contributors and (2) a large number of passive consumers (such as learners). In such cultures, strong input filters exist based on:

- substantial knowledge is necessary for contributions (e.g.: the in-depth understanding of established fields of inquiry or the need to learn specialized high-functionality tools); and
- extensive quality control mechanisms exist (e.g.: the certification of professionals or low acceptance rates for conference and journal articles); and
- large organizations and high investments for production are required (e.g.: film studios such as Hollywood or newspaper production facilities);

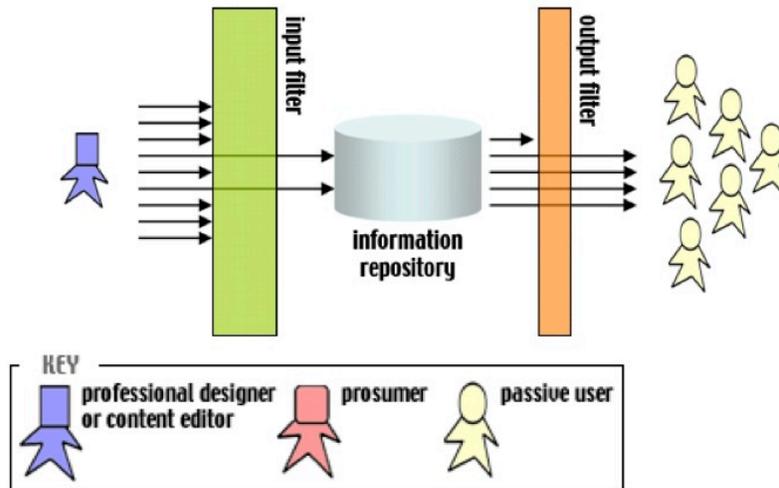


Figure 3.2: MODEL-AUTHORITATIVE underlying Professionally Dominated Cultures

A consequence that the strong input filters prevent and reject contributions is that relatively small information repositories are created. The advantage of this model (this is at least the basic underlying assumption) is the likelihood that the quality and trustworthiness of the accumulated information is high because the strong input filters will reject unreliable and untrustworthy information. Based on the smaller size of the resulting information repositories, relatively weak output filters are required.

MODEL-DEMOCRATIC (see Figure 3.3) underlies *democratized cultures* [Fischer, 2002; von Hippel, 2005]); it is characterized by weak input filters allowing users not only to access information but to become active contributors by engaging in *informed participation*. The weak input filters result in much larger information repositories (with information repositories such as the World Wide Web being the prime example).

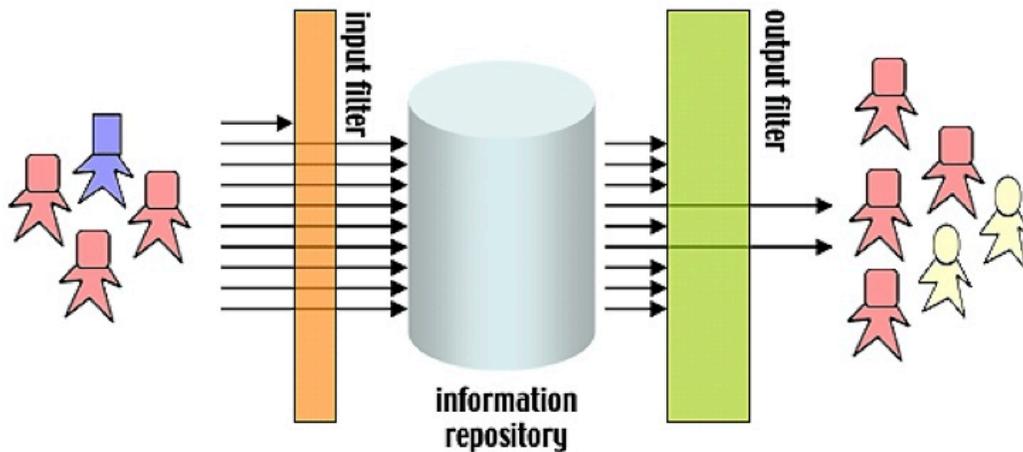


Figure 3.3: MODEL-DEMOCRATIC underlying Democratic Design Cultures

The meta-design framework supports MODEL-DEMOCRATIC on the *technical* side with powerful tools for (1) creating content (such as Wiki substrates and end-user development environments); (2) organizing content (such as supporting collections); and (3) distributing content (such as powerful search capabilities and recommender systems). On the *social* side, meta-design supports (1) active contributors (who master design tools and who are motivated to contribute); (2) curators (who organize large information repositories); and (3) coaches (who assist in helping learners to identify and locate relevant information).

The advantages and disadvantages of the two models are complementary. *MODEL-AUTHORITATIVE* greatly limits that “all voices can be heard” thereby excluding relevant information and divergent opinions. Most people in this model are limited to accessing existing information, denying them a voice even in the context of personally meaningful problems and in situations in which specialized idiosyncratic knowledge would represent a unique contribution.

Major limitations of MODEL-DEMOCRATIC are the potentially reduced trust and reliability of the content of the information repositories based on the weak input filters. The amount of available information is exploding, and since too much information consumes the scarce resource of *human attention*, the large information repositories will be a mixed blessing unless we are able to develop strong new output filters (e.g.: powerful search mechanisms to find relevant information, collaborative filtering, recommender and tagging systems, and user and task models to personalize information).

4. EXAMPLES OF CO-DESIGNED ENVIRONMENTS

By empowering designers and teachers to act as meta-designers, users and learners can become co-designers and active contributors rather than being passive consumers of the artifacts and information provided to them. This section

briefly describes three different examples instantiating the ideas and models discussed in the previous section.

SketchUp, 3D Warehouse, and Google Earth: Sharing 3D Models. Google is interested in modeling the whole world in 3D and to use Google Earth for exploring this world (see Figure 4.1 for an example). A development team at Google alone cannot achieve this objective. The most feasible approach is to engage the whole world in this major undertaking with MODEL-DEMOCRATIC. To do so poses a number of challenging problems for participants acting as active contributors. They need to learn (1) SketchUp, a high-functionality environment for 3D modeling (<http://sketchup.google.com/>); (2) the mechanisms of sharing 3D models by uploading them from SketchUp to the 3D Warehouse; and (3) how to download models from the 3D Warehouse and view them in Google Earth. In order to motivate and empower enough people, we have explored in close collaboration with researchers from Google new learning mechanisms for SketchUp to allow everyone who wants to contribute learn to do so by reducing the “thickness” of the input filters.

The 3D Warehouse (<http://sketchup.google.com/3dwarehouse/>) is an information repository for the collection of models created by all users who are willing to share their models. It contains millions of models from different domains and it supports collections to organize models and supports ratings and reviews by the participating community. It lets viewers connect with the owners of models. It has weak input filters (such as content policies), mechanisms to ensure the quality of user contributions (such as tagging and ratings), and an emerging set of output filters (such as search support and different sorting algorithms). It is integrated with SketchUp as the design environment, and Google Earth as the viewing environment, which has the capability of showing 3D objects that consist of users' submissions and were developed using SketchUp. Figure 4.1 shows the downtown area of the city of Denver in 3D. An interesting research challenge is to explore the effectiveness of different reward structures to motivate users to participate in the collaborative effort to model the whole world.



Figure 4.1: Downtown Denver in 3D

Distributed Scientific Communities. We have designed and seeded a wiki-based socio-technical environment (<http://swiki.cs.colorado.edu/CreativeIT>) to foster and support the emerging *CreativeIT Community*, consisting of participants (researchers, artists, graduate students) in the NSF research program on “Creativity and IT” (<http://www.nsf.gov/pubs/2007/nsf07562/-nsf07562.htm>). The unique challenges of supporting this specific community with MODEL-DEMOCRATIC are that people working in interdisciplinary projects or in niches of their disciplines are often isolated in their local environments and are unaware of relevant work in other disciplines. Based on this research, we have developed a deeper understanding of how technical and social environments can be changed through design interventions.

Courses-as-Seeds. Courses-as-seeds [dePaula et al., 2001] is an educational model that explores meta-design in the context of fundamentally changing the nature of courses taught in universities. Its goal is to create *cultures of participation* [Fischer, 2011] that are situated in the context of university courses by supporting a *community of learners* model [Rogoff et al., 1998]. Traditionally, the resources provided by an instructor such as lectures, readings, and assignments define the content of a course. By involving students as active contributors, courses do not have to rely only on the intellectual capital provided by an instructor. Our courses (a large number of them being available at: <http://l3d.cs.colorado.edu/~gerhard/courses/>) are conceptualized based on the

seeding, evolutionary growth, reseeding model (see Figure 3.1), in which the instructor provides the initial seed rather than a finished product and the content of a course evolves over time through contributions of the students.

5. IMPLICATIONS

Our research to empower learners as co-designers with meta-design is creating new opportunities and challenges for rethinking the co-evolution between a new understanding of learning, innovative technologies and new learning organizations and explore new design concepts with important and broad implications [Collins & Halverson, 2009]. A few of those will be briefly discussed.

Harness Social Creativity. Meta-design and cultures of participation challenge the assumption that information must move from teachers and other credentialed professionals to passive learners and consumers. As long as only experts (including: teachers, professionals in different disciplines, commercial producers of software and movies) can determine what is right and worthwhile to be published, we will never be in a position to harness people's creativity and local knowledge [von Hippel, 2005]. By arguing that meta-design opens the opportunity to harness social creativity, we do not imply that it is the preferred model for *all* human activities. A deeper understanding is needed under which conditions and for which kinds of activities MODEL-AUTHORITATIVE is the preferred model rather than MODEL-DEMOCRATIC.

Quality of Information Repositories. An analysis [Giles, 2005] of the quality of articles in the Encyclopedia Britannica (based on MODEL-AUTHORITATIVE) with Wikipedia (based on MODEL-DEMOCRATIC) has come to the conclusion that "Wikipedia comes close to Britannica in terms of the accuracy of its science entries". This study and the interpretation of its findings has generated a controversy and [Tapscott & Williams, 2006] has challenged the basic assumption that a direct comparison between the two encyclopedias is a relevant issue: "Wikipedia isn't great because it's like the Britannica. The Britannica is great at being authoritative, edited, expensive, and monolithic. Wikipedia is great at being free, brawling, universal, and instantaneous."

There are many more open issues to be investigated including: (1) errors will always exist so the question will be which model is better suited to deal with errors over time?; (2) how do knowledge workers acquire the important skill of being critical of information rather than blindly believing in what others (specifically "experts") are saying?; and (3) ownership may be a crucial dimension because voluntary active contributors have a greater sense of ownership and are thereby more willing to make sure that errors will be fixed.

Motivation for Participation. Being an active contributor requires more effort and more time than being a passive consumer. In order for MODEL-DEMOCRATIC

to be a viable alternative, we have to explore the fundamental question: *what motivates people to participate* [Fischer, 2011]? Active contributors are often lifelong learners, domain professionals, competent practitioners, and discretionary users and should not be considered simply as naïve users. They worry about tasks, they are motivated to contribute and create good products, they care about personal growth, and they want to have convivial tools. The experience of having participated in the framing and solving of a problem or in the creation of an artifact makes a difference to those who are affected by the solution and therefore consider it personally meaningful and important: *“people are more likely to like a solution if they have been involved in its generation; even though it might not make sense otherwise”* [Rittel, 1984]. Active contributors require and value different systems than passive consumers: control, ownership, engagement, expressiveness, usefulness, and sharing are more relevant to them than “ease of use” [Fischer, 2002].

Supporting the “Long Tail”. In systems supported by MODEL-DEMOCRATIC there is something for everybody. Not all active contributors are equally creative but *most people have some unique expertise* residing in the “Long Tail” [Anderson, 2006; Collins et al., 2009] which is more likely to become externalized and documented with weak input filters. Providing platforms for user-generated content and motivation for participation, Long Tail environments can achieve coverage that a small team of professionals is unable to generate (as argued and demonstrated with the examples described earlier).

6. CONCLUSIONS

The design of innovative information and communication technologies to support learning and education has the potential to change *what we learn, how we learn, where we learn, and who we learn with*. Meta-design provides a framework for making learning a part of life and thereby characterizing learning (1) of being more a social than an individual process; (2) of not having a beginning or an end; (3) being integrated into human lives; and (4) not being completely dependent on teachers. The fundamental transformation supported by meta-design is to empower learners to be co-designers and active contributors engaged in self-directed learning activities complementing their role as consumers of ideas and knowledge provided to them by teachers and restricted by curricula.

7. ACKNOWLEDGEMENTS

The ideas, concepts, arguments, and system developments described in this paper have been jointly developed over the last two decades with former and current members of the Center for Lifelong Learning & Design (L3D) at CU Boulder (<http://l3d.cs.colorado.edu/wordpress/>). Financial support for our research was

provided by a large number of research grants from the National Science Foundation.

8. REFERENCES

- Anderson, C. (2006) *The Long Tail: Why the Future of Business Is Selling Less of More*, Hyperion, New York, NY.
- Benkler, Y. (2006) *The Wealth of Networks: How Social Production Transforms Markets and Freedom*, Yale University Press, New Haven.
- Bruner, J. (1996) *The Culture of Education*, Harvard University Press, Cambridge, MA.
- Collins, A., Fischer, G., Barron, B., Liu, C., & Spada, H. (2009) "Long-Tail Learning: A Unique Opportunity for CSCL?" In *Proceedings (Vol 2) of CSCL 2009: 8th International Conference on Computer Supported Collaborative Learning, University of the Aegean, Rhodes, Greece*, pp. 22-24.
- Collins, A., & Halverson, R. (2009) *Rethinking Education in the Age of Technology: The Digital Revolution and the School*, Teachers College Press New York, NY.
- dePaula, R., Fischer, G., & Ostwald, J. (2001) "Courses as Seeds: Expectations and Realities." In P. Dillenbourg, A. Eurelings, & K. Hakkarainen (Eds.), *Proceedings of the European Conference on Computer-Supported Collaborative Learning*, Maastricht, Netherlands, pp. 494-501.
- Engeström, Y., & Sannino, A. (2010) "Studies of Expansive Learning: Foundations, Findings and Future Challenges," *Educational Research Review* 5(1), pp. 1-24.
- Fischer, G. (1998) "Making Learning a Part of Life—Beyond the 'Gift-Wrapping' Approach of Technology." In P. Alheit, & E. Kammler (Eds.), *Lifelong Learning and Its Impact on Social and Regional Development*, Donat Verlag, Bremen, pp. 435-462.
- Fischer, G. (2002) *Beyond 'Couch Potatoes': From Consumers to Designers and Active Contributors*, in *Firstmonday (Peer-Reviewed Journal on the Internet)*, available at http://firstmonday.org/issues/issue7_12/fischer/.
- Fischer, G. (2011) "Understanding, Fostering, and Supporting Cultures of Participation," *ACM Interactions* XVIII.3 (May + June 2011), pp. 42-53.
- Fischer, G., & Ostwald, J. (2002) "Seeding, Evolutionary Growth, and Reseeding: Enriching Participatory Design with Informed Participation," Malmö University, Sweden, pp. 135-143.
- Fischer, G., & Sugimoto, M. (2006) "Supporting Self-Directed Learners and Learning Communities with Sociotechnical Environments," *International*

- Journal Research and Practice in Technology Enhanced Learning (RPTEL)*, 1(1), pp. 31-64.
- Giles, J. (2005) "Internet Encyclopedias Go Head to Head," *Nature*, 438, pp. 900-901.
- Illich, I. (1971) *Deschooling Society*, Harper and Row, New York.
- Jenkins, H. (2009) *Confronting the Challenges of Participatory Cultures: Media Education for the 21st Century*, MIT Press, Cambridge, MA.
- Luckin, R. (2010) *Re-Designing Learning Contexts* Routledge, London.
- National-Research-Council (1999) *Being Fluent with Information Technology*, National Academy Press, Washington, DC.
- National-Research-Council (2003) *Beyond Productivity: Information Technology, Innovation, and Creativity*, National Academy Press, Washington, DC.
- Ong, W. J. (1982) *Orality and Literacy*, Routledge, London.
- Rittel, H. (1984) "Second-Generation Design Methods." In N. Cross (Ed.), *Developments in Design Methodology*, John Wiley & Sons, New York, pp. 317-327.
- Rogoff, B., Matsuov, E., & White, C. (1998) "Models of Teaching and Learning: Participation in a Community of Learners." In D. R. Olsen, & N. Torrance (Eds.), *The Handbook of Education and Human Development — New Models of Learning, Teaching and Schooling*, Blackwell, Oxford, pp. 388-414.
- Schön, D. A. (1983) *The Reflective Practitioner: How Professionals Think in Action*, Basic Books, New York.
- Schuler, D., & Namioka, A. (Eds.) (1993) *Participatory Design: Principles and Practices*, Lawrence Erlbaum Associates, Hillsdale, NJ.
- Simon, H. A. (1996) *The Sciences of the Artificial*, third ed., The MIT Press, Cambridge, MA.
- Tapscott, D., & Williams, A. D. (2006) *Wikinomics: How Mass Collaboration Changes Everything*, Portofolio, Penguin Group, New York, NY.
- von Hippel, E. (2005) *Democratizing Innovation*, MIT Press, Cambridge, MA.
- Winograd, T., & Flores, F. (1986) *Understanding Computers and Cognition: A New Foundation for Design*, Ablex Publishing Corporation, Norwood, NJ.