Summary and Recommendations

Creativity plays a crucial role in culture; creative activities provide personal, social, and educational benefit; and creative inventions ("better recipes, not just more cooking") are increasingly recognized as key drivers of economic development. But creativity takes different forms at different times and in different places. This report argues that, at the beginning of the 21st century, information technology (IT) is forming a powerful alliance with creative practices in the arts and design to establish the exciting new domain of information technology and creative practices—ITCP. There are major benefits to be gained from encouraging, supporting, and strategically investing in this domain.

INFORMATION TECHNOLOGY AND CREATIVE PRACTICES

Alliances of technology and creative practices have often emerged in the past. In the 19th century, for example, optical, chemical, and thin-film manufacturing technologies converged with the practices of the pictorial arts to establish the new domain of photography. Then, photographic technology became further allied with the practices of the performing arts, giving rise to the domain of film. The cultural and economic consequences of these developments have been profound. The emerging alliance of information technology with the arts and design has, this committee believes, even greater potential.

ITCP has already yielded results of astonishing variety and significant cultural and economic value. These results have taken such forms as innovative architectural and product designs, computer animated films, computer music, computer games, Web-based texts, and interactive art installations, to name just a few. They have developed from individual, group, and institutional activities; the processes by which they have been produced have spanned both the commercial and not-for-profit worlds and the formal and informal economic sectors. The products of ITCP have begun to appear in many different countries, in ways that reflect cultural, economic, and political differences.

IT has now reached a stage of maturity, cost-effectiveness, and diffusion that enables its effective engagement with many areas of the arts and design—not just to enhance productivity or to allow more efficient distribution, but to open up new creative possibilities. There is a highly competitive race for leadership in this domain. The potential payoffs from success in the near- and long-term futures are enormous: billion-dollar industries, valuable exports, thriving communities that attract the best and the brightest, enriched cultural experiences for individuals and communities, and opportunities for global cultural visibility and influence.

By definition, there is no formula for creativity. But there are effective ways to invest in establishing conditions necessary for ITCP, in overcoming impediments, and in providing incentives. Furthermore, there are ways to recognize and reward creative contributions and to derive social benefit from them. In appropriate combination, these measures can add up to powerful strategies for encouraging, supporting, and reaping the rewards of ITCP. Development along with implementation of such strategies is the challenge addressed by this report.

MULTILEVEL STRATEGIES FOR ITCP

ITCP can be engaged at multiple levels—by individual artists and designers who deal with IT tools, media, and themes; in the structuring and management of cross-disciplinary research and production groups working in the ITCP domain; in directing educational and cultural institutions with interests in ITCP; at the level of regional development strategy aimed at fostering ITCP clusters; as an aspect of national economic and cultural policy; and in multinational collaborative efforts. All of these levels are important, and there are cross-connections among them. There is, therefore, considerable advantage in coordinated, multilevel strategies for encouraging, supporting, and benefiting from ITCP.

PROVIDING NEW TOOLS AND MEDIA FOR ARTISTS AND DESIGNERS

Individual artists and designers have experimented with IT since its earliest incarnations. Artistic exploration of the possibilities of computer graphics, for example, now extends back more than 30 years, and 40 years for computer music. As IT has matured and been assimilated into the mass market, the IT tools and media available to artists and designers have become both more diversified and more affordable. There are popular, standardized tools for performing such tasks as creating, editing, and distributing images, audio, and text; there are variants on standard tools customized to the needs of particular artists or designers; and there are highly specialized, purpose-built tools used by nobody but their creators.

To a software developer or an information services manager, it might seem that the keys to ITCP are simply equipment and software—developing and providing access to standard, commercial IT tools for artists and designers. This perspective is useful as far as it goes, and it can provide a good way to get started with ITCP, but in the long run it is an insufficiently rich or flexible one. We make our tools; then our tools make us.[1] Furthermore, software tools encode numerous assumptions about the making of art and design—precisely the sorts of presuppositions that truly creative practitioners will want to challenge. And the more software tools emphasize ease of use or familiar metaphors, the more they must depend on restrictive assumptions in order to do so. Such tools not only must be available, but they also must be objects of critical reflection; they must be open to adjustment and tweaking, they must support unintended and subversive uses—not just anticipated ones—and they must not be too resistant to being torn apart and reconceived. If creative practice can develop the powerful spaces and tools that it needs, like the electronic easel or electronic studio, these spaces and tools could help transform or enlarge the metaphors, spaces, and tools (office, desktop, files) that the rest of us have to work with.

The relationship between IT professionals and artists and designers will be of limited value if it is conceived simply as one of software (or hardware) producer and consumer. It should, instead, be one of flexible and thoughtful collaboration in which the roles of software designer and user are not rigidly distinguished. The advances made by IT researchers may suggest new forms of art and design practice,

[1]Inspired by Marshall McLuhan, 1954, "Notes on the Media as Art Forms," *Explorations* 2 (April): 6-13.

while the questions raised by artists and designers may provide new ways of thinking about IT—ITCP work challenges the boundaries of traditional disciplines. Modular, reusable and recombinable code elements may support critical reconceptualization more readily than closed, proprietary software products. Open source development may provide better opportunities for cross-disciplinary collaboration, customization, and reconceptualization than tools developed and marketed as protected intellectual property—no matter how powerful and attractive those tools may be.

PROVIDING OPPORTUNITIES TO DEVELOP ITCP SKILLS

In general, ITCP depends on opportunities for learning across multiple disciplines—some mix of the arts and design plus IT concepts and tools. The growing numbers of artists and designers becoming skilled programmers or hardware developers, like the smaller number of computer scientists and technologists engaging seriously with the arts and design, demonstrates that this is feasible. But it is not easy: Colleges and universities focus mostly on established disciplines, and the cross-disciplinary programs that do exist vary widely in their institutional support, effectiveness, and quality.

Like other professionals, artists and designers can do more with IT if they become deeply conversant with its capabilities and limitations. Achieving that result requires far more than training on standard tools, and it also demands an ability to understand tools and media critically—in cultural and historical context. Such critical thinking about tools is much less typical of education and training in IT, a difference that contributes to the asymmetric participation of artists and computer scientists in ITCP. To date, it seems that artists and designers have made greater efforts to engage IT seriously than computer scientists and technologists have made to acquire deep understanding of creative practices in the arts and design. It is easier to find designers who can program than programmers who can design, or composers comfortable with signal processing than specialists in signal processing who can compose or perform at high levels of proficiency. This imbalance could change, with outreach to the computer science community and interest in ITCP among those who provide funding and other incentives and rewards.

Although motivated individuals can and do acquire complementary IT and arts or design skills, significant ITCP work can also be produced by cross-disciplinary partnerships between computer scientists and artists or designers. This approach has the advantage of requiring that fewer skills be mastered by individual team members, and it is often essential for large projects, but there are some inherent difficulties. Progress in collaborative ITCP requires effective dialogue between artists and designers and IT professionals. Differences in professional culture, styles, and values, as well as communication problems, can confound effective collaboration. Yet there are strong traditions of successful cross-disciplinary collaboration in architecture (particularly as computer-aided design/computer-aided manufacturing (CAD/CAM) technology plays an increasing role), in film production, and in the creation of video games, and there have been some successful pairings of artists and technologists to produce visual works, performances, and installations.

CREATING ENVIRONMENTS THAT SUPPORT ITCP

ITCP work can be done in many different places. And the diversity of venues matters, since each type of venue represents different tradeoffs and provides different combinations of opportunities, constraints, and comparative advantage. So an effective ITCP development strategy is likely to be a multivenue one.

ITCP venues may occupy physical or virtual spaces, be large or small, range from loosely organized collectives to formal programs, and be either free-standing or connected to established institutions. Specialized exhibitions, performance festivals, presentation and lecture series, conferences, Internet forums, and display and performance sites have all played important roles in the growth of ITCP communities. By contrast, mainstream arts and design organizations—museums, galleries, arts and design fairs, arts and design publishers, and so on—have played a lesser role, although they have begun to embrace ITCP more as the products of ITCP have played a larger cultural role and as these products have developed in quality and interest.

Much pioneering exploration of ITCP has taken place in studio-laboratories, which build on the tradition of earlier centers of cross-disciplinary research and education in the arts, design, and new technology of the time, such as Germany's Bauhaus in the pre-World War II years, the postwar New Bauhaus in Chicago, and the Center for Advanced Visual Studies established by Gyorgy Kepes at the Massachusetts Institute of Technology (MIT) in the 1960s. MIT's Media Laboratory has been among the largest and most visible, and it has generated affiliates in Europe and Asia. However, the Media Lab's combination of substantial laboratory and human resources with an atelier style of research and education, building on a consortium of industry funders, is difficult to replicate outside the context of a leading research university with strong industrial connections. Some universities, such as Carnegie Mellon University, have formed special cross-disciplinary centers that undertake ITCP, and several arts schools, such as the California Institute of the Arts and the Art Center College of Design in Pasadena, have transformed their curricula to incorporate

IT, yielding numerous focused ITCP activities. Some film schools have shifted their emphasis from traditional to digital production and distribution technologies, and most architecture and design schools have supplemented or supplanted drawing boards with CAD. Several universities have begun to develop cross-disciplinary study programs in aspects of ITCP. But a key challenge, particularly in times of tight finances, is to find effective ways to fund these programs—and to frame them in ways that are pedagogically sound and appropriately adaptive to the continuing evolution of ITCP.

In Canada and Europe, and emerging in Asia and Australia, major efforts are under way to develop standalone, government-backed ITCP centers. Such centers are typically conceived of as instruments of arts and cultural policy, rather than as equivalents of national research laboratories. This is an arena in which the United States lags. In principle, such centers can provide considerable flexibility and freedom of intellectual direction. On the down side, they are vulnerable to changes in government spending priorities, they can lose the very independence that makes them attractive if they shift to executing contracts from industry, and they are usually less able to draw effectively on the laboratories and human resources of large universities.

The technology required for ITCP can be expensive, and ambitious ITCP productions can require major funding. Given the breadth of ITCP, some funding is available through commercial channels. It normally requires close engagement with popular culture and mass audiences, with all the constraints and opportunities that this implies. This path is illustrated by the film and entertainment industries—these ITCP pioneers overcame difficulty and expense and now can produce major commercial successes. A focused example is the flourishing video game industry, a direct outcome of the rise of ITCP. It obviously would not be possible at all without the necessary IT, and its products define a new art form that also resonates with the general public. It has found some highly innovative ways to combine centralized research, development, and marketing with large-scale open-source strategies, and it has evolved unique distribution strategies.

Operating on a small scale and often producing innovative work through commissions from enlightened patrons is another group of players that straddle the boundary between commerce and the arts: Independent architectural design, product design, graphic design, and music and video production houses now make extensive use of IT tools and media, and they frequently have IT specialists on staff. In some cases, this amounts to little more than straightforward use of standard, commercial tools. But more adventurous and innovative houses have seized the opportunity, through IT, to open up some exciting new domains. This is particularly evident in the move of architects into CAD/CAM design and construction—with the resulting emergence of new architectural idioms—and the move of graphic designers into work that is more interactive.

Much important ITCP work occurs outside the marketplace. In addition to academic efforts, individual, independent artists and designers, operating mostly on a small scale, are responsible for a crucial segment of ITCP. By virtue of their independence, they are well positioned to provide perspectives that challenge mainstream thinking and to engage industry as catalytic outsiders who can instigate new ways of thinking about products and processes. Many forms of traditional art production, such as painting and writing, are labor-intensive and modest in their requirements for investments in technology, but ITCP is often much more capital-intensive. This increased need for capital presents a chronic problem for independents; they often operate on a shoestring, struggle to get access to technology and expertise, and must make whatever technology investments they can manage from project-by-project funding. They usually depend on some mix of the gallery and patronage structures of the art world, arts foundation grants, and relationships with sympathetic educational institutions and corporations.

ITCP activity in all of these venues tends to cluster geographically. Fostering such clusters—with a vital mix of commercial, non-profit, academic, design and production house, and independent practitioner activity—can play an important role in regional economic development. There can be major direct benefits to local economies, and indirect (but potentially even more important) benefits in the form of better design and higher levels of innovation distributed over many sectors of the economy.

In addition, by its very nature, ITCP lends itself to efficient electronic connection of scattered islands of activity. Writers and photographers can submit their work electronically to distant publishers, architects can form geographically distributed design and construction teams, film studios in Hollywood can link electronically to postproduction houses in London or animation shops in Korea, and so on. That capability for connectivity is leading, increasingly, to multinational ITCP alliances and organizations. Such a capability can be particularly important in contexts—such as in developing nations—where the local culture supports some unique ITCP cluster and electronic connectivity adds value to that cluster by providing wider access to resources and markets. It is also important in contexts—such as those of Australia, New Zealand, and Singapore—where small but highly educated populations, combined with the effects of distance, make concentration on high-value, immaterial, information goods and services particularly attractive.

FOSTERING THE CULTURE OF INFORMATION TECHNOLOGY AND CREATIVE PRACTICES

Providing new tools and media for artists and designers, providing opportunities to develop ITCP skills, and creating environments that support ITCP are all necessary to form thriving ITCP clusters, but they are not in themselves sufficient. It is also essential to foster the culture of ITCP—the flow and exchange of ideas among those engaged, the development of a sense of intellectual community, the representation of ideals and values, and the recognition and validation of outstanding work.

The academic environment, in particular, is central to the future of ITCP. That is where talent is cultivated, and that is where research and practice of various kinds can take place largely without market strictures. At present, a gulf exists between computer science and the arts and design. Although some computer scientists bridge that gulf—and contribute considerably to ITCP—that activity often happens outside their department. Although some arts departments have been skeptical of "new-media" programs, in general the arts and design on campus have welcomed ITCP more than have computer science departments. The lack of welcome from computer science departments reflects a lack of appreciation of ITCP's potential to contribute to the advance of computer science as a field, as well as concern about already tight curricula. At the same time, arts and design departments on campuses and arts schools have sought to internalize ITCP facilities and to develop their own research and teaching programs in ITCP. The situation echoes earlier efforts to formalize computer science as a field, establish a theoretical foundation for it, and provide it with some level of autonomy from its predecessor and sister fields. But it is important to explore the potential for constructive interaction between the arts and design and computer science before universities—and practitioners—conclude that "parallel play" is the way to go.

Building academic clusters is a nontrivial challenge. Not only are there cultural differences among the constituent disciplines, but there are also significant differences in expectations for funding, use of time, use of graduate students, definitions of what is acceptable work, and so on. Special centers, seminars, and other venues are being tried on campuses, a kind of institutional experimentation that is vital to developing ITCP. They help to frame and sustain ITCP projects. The time is ripe for academic experimentation with ITCP, from course content and curricula to institutional options and incentives.

Education, collaboration, funding, and professional advancement all depend on how ITCP is received. Because ITCP spans so many activities, there is feedback from the commercial space and popular culture—a powerful reinforcement on the design end—and there is more ambiguous feedback through academic institutions (faculty and administrators); publications, exhibitions, performances, and prizes, as well as those who select for them; and funders of research and the arts.

Because the field of ITCP is young and dynamic, ITCP production is hard to evaluate. Traditional review panels—representing funders; owners and managers of conventional display, performance, or publication outlets; and those making personnel decisions at academic institutions—may be hampered by their members' ties to single disciplines and the absence of a time-tested consensus about what constitutes good work in ITCP and why. This problem is typical of new fields drawing from multiple disciplines, albeit aggravated by the contrast between computer science and the arts and design. It is offset somewhat by a flourishing array of conferences and other forums, in both virtual and real space, that provide a sense of community and an outlet as well as feedback. Effective evaluation, validation, and recognition of ITCP work are essential for this domain to progress. Building on traditions in the arts and design, prizes can be powerful for stimulating and recognizing excellence in ITCP.

A NEW FORM OF RESEARCH

ITCP can constitute an important domain of research. It is inherently exploratory and inherently transdisciplinary.[2] Concerned at its core with how people perceive, experience, and use information technology, ITCP has enormous potential for sparking reconceptualization and innovation in IT. In execution, it pushes on the boundaries of both IT and the arts and design. Computer science has always been stimulated by exposure to new points of view and new problems, which are ever-present in the arts and design. Because of the breadth of use to which artists and designers put different forms of IT, and because they typically are not steeped in conventional IT approaches, artists' and designers' perspectives on tools and applications may provide valuable insights into the needs of other kinds of IT users. The needs and wants of artists and designers can suggest new ways of designing and implementing IT. Engaging their perspectives is a logical extension of recent trends in cross-disciplinary computer science research.

Recently, for example, artists and designers have brought new concerns to the design and implementation of sensor systems, distributed control systems and actuators, generative processes and virtual reality, and the Internet and other networks. Their interests in performance and in engaging the public present challenges for system interactivity; their interests in improvisation present new opportunities for exploring human-machine interaction. Although artists and computer scientists have long interacted in such spheres as computer graphics and music, almost any form of IT may be adopted or adapted for uses in the arts and design. This flexibility of purpose parallels the plasticity of the computer itself—and that helps to explain why artists' concerns may motivate new combinations as well as new forms of IT.

It is important to recognize, however, that serious ITCP research goes beyond appropriation of established IT concepts and techniques for artistic or design purposes, or use of straightforward examples

[2]In transdisciplinary ITCP work, artists and designers interact as peers with computer scientists, a model that is described in detail in Chapter 4.

drawn from the arts and design to demonstrate the potential applications of new IT. It requires drawing on deep understanding of *both* IT and the arts and design to formulate scientifically interesting new questions in ITCP, and to see the subtle cultural implications of relevant new science. Issues arising from the arts and design have motivated challenging and important domains of computer science and technology research, such as three-dimensional geometric modeling and scene rendering directed at the practices and needs of designers and animators. Sometimes arts-oriented researchers raise cultural, social, ethical, and methodological questions for computer scientists that would not be obvious in a more narrowly focused technological context. Conversely, outcomes of computer science research may challenge artists and designers to rethink their established assumptions and practices (rethinking that includes an evolution from artifact creator to process mediator), as when architects engage the possibilities of curved-surface modeling and associated CAD/CAM fabrication techniques, or when photographers ponder the differences in the roles of digital and silver-based images as cultural products and as visual evidence. And there are areas, such as augmented reality, tangible computing, lifelike computer animation of characters, and user-centered evaluation of computer systems, that are probably best regarded as the joint outcomes of questions posed and investigations conducted by computer scientists and by artists and designers. These developments suggest that the value of ITCP lies not just in the capacity of each field to answer questions posed by the other, but also in the opportunity for each field to gain fresh, sometimes uncomfortable, perspectives on itself.

MAKING ITCP HAPPEN

The broad scope of ITCP implies that it derives funding from both commercial activity—notably in design and entertainment contexts—and non-profit activity. The latter is where support is particularly uncertain yet essential, since it is in non-profit contexts that much experimentation takes place and some of the broadest public, participant access becomes possible. The hybrid nature of ITCP tends to confound its funding. In the United States, exploratory and productive work in the arts and at the non-commercial frontiers of design is likely to be funded by private philanthropy, while in computer science the leading funders of basic research are government agencies, often in support of specific agency missions. Computer science research grants are larger (by an order of magnitude) than grants (or prizes) typically available to artists—and they tend to be tied to the advances in scientific knowledge or the specific kinds of applications of concern to their funders.

Advancing ITCP requires new approaches to funding. A first step is recognition by both the arts and computer science patrons that topics in ITCP are legitimate; next must come support for exploration of the intersections between IT and the arts and design, and with that support for new kinds of technical and social and intellectual infrastructure for undertaking and providing access to ITCP. Those new approaches, in turn, may require new skills and participants in funders' decision-making processes. Grant program definitions should specifically embrace ITCP, but without that, progress in ITCP will depend on grant seekers' ingenuity in influencing program definitions and relating their ideas to existing programs.

In addition to monetary support, ITCP depends on resolving concerns about intellectual property rights. Not only does ITCP feature a broad range of content and a broad range of expression, but its production can also involve creative reuse or adaptation of previously generated content or expression. It also requires attention to the archiving and preservation of IT-based works, both those of a fixed nature and those designed to change through interactivity or other factors.

The rise of ITCP and the process of contemplating its future point to the need for better data on arts-related activities and trends. Although imperfect, the data available on scientific and technical research is better than that for arts activities. The lack of good data hinders effective planning and policy making.

RECOMMENDATIONS

Realizing the potential of ITCP requires actions on many fronts—by individuals, organizations, and funders of different kinds. The benefits will accrue broadly—in multiple sectors of the economy, geographic regions, and disciplines. Other efforts already address the roles of established arts institutions—museums, galleries, theaters, and so on—in relation to IT-based art works and performances. This report concentrates its recommendations on those most responsible for nurturing the talent and the explorations that are the essence of ITCP. The recommendations below build on discussions in the body of the report, which explores the ecology of creative practices and the components of the strategies through which ITCP can thrive.

FOR EDUCATORS AND ACADEMIC ADMINISTRATORS

1. Support the achievement of fluency in information technology (IT), and the development of critical and theoretical perspectives on IT, by arts and design students through the provision of suitable

facilities, opportunities for hands-on experience with IT tools and media, and curricula that engage critical and theoretical issues relating to IT and to information technology and creative practices (ITCP).

2. Support educational experiences for computer science students that provide direct experience in the arts and design, critical discussion, and formation of broader cultural perspectives—not merely as semi-recreational enrichment, but at a sufficiently challenging level to raise hard questions about the social and cultural roles both of science and technology and of the arts and design.

3. Foster exploration of ITCP through incentives and experimentation with a range of informal (e.g., workshops and seminars) and formal vehicles (e.g., centers, awards)—in particular, by building firmly and boldly on demonstrated local (and often small-scale) strengths and productive relationships already in place.

4. Support curricula, especially at the undergraduate level, that provide the necessary disciplinary foundation for later specialization in ITCP.

For Foundations, Government Agencies, and Other Funders

5. Allocate funding not only to support work by specialists in established and recognized areas of IT and of the arts and design, but also to foster collaborations that open up new areas of ITCP.

6. Structure proposal review processes to encourage not only continued development of established and recognized areas of IT and of the arts and design, but also higher-risk, longer-horizon efforts to develop ITCP.

7. Provide program managers with more time and leeway to learn about new fields and new kinds of grantees; encourage mobility among grant makers, artists, designers, and computer scientists.

8. Develop a new grant-making category for tool (instrument) building, emphasizing designs that are extensible and tools that provide support for improvisation, and for providing broad access to the resulting tools. Expand research program support for work in aspects of distributed control, sensors and actuators, video and audio processing, human-computer interaction, information retrieval, artificial intelligence, networking, embedded systems, generative processes, and other technological areas that are critical to advancing ITCP, with a particular focus on arts-and-design-inspired applications of these technologies that extend beyond conventional uses.

9. Factor infrastructure and archiving and preservation needs into grant levels because this support is essential to enable future work in ITCP.

10. Support the establishment of new prizes for excellence in ITCP and the development of curated Web sites for its display or performance.

11. To support policy decision making, underwrite a better knowledge base—ranging from the history of ITCP to the details of who is doing what, where, when, and how—that parallels the knowledge base in scientific and engineering fields.

12. Underwrite research on the formation of creative clusters and the role that ITCP can play in promoting regional development.

13. Provide support for the creation and maintenance of networks of organizations (composed of participants from academia, industry, and cultural institutions) involved with ITCP.

For Industry

14. Seek opportunities to develop new products and services relating to the growing field of ITCP and to participate in the formation of ITCP clusters.

15. Pursue relationships with centers of ITCP activity, and seek opportunities to engage artists and designers who can contribute to the development of ITCP products and services.

For the National Academies

16. Organize a symposium series on Frontiers of Creative Practice (paralleling the Frontiers of Science and Frontiers of Engineering series) to bring together a cross section of young artists, designers, scientists, and technologists working within ITCP.

1 Information Technology, Productivity, and Creativity

The benefits of information technology (IT) extend far beyond productivity as it is usually understood and measured. Not only can the application of IT provide better ratios of value created to effort expended in established processes for producing goods and delivering services, but it can also reframe and redirect the expenditure of human effort, generating unanticipated payoffs of exceptionally high value. Information technology can support inventive and creative practices in the arts, design, science, engineering, education, and business, and it can enable entirely new types of creative production. The scope of IT-enabled creative practices is suggested (but by no means exhausted) by a host of coinages that have recently entered common language—computer graphics, computer-aided design, computer music, computer games, digital photography, digital video, digital media, new media, hypertext, virtual environments, interaction design, and electronic publishing, to name just a few.

The benefits of such practices have economic, social, political, and cultural components. IT-enabled creative practices have the potential to extend benefits broadly, not only to economic and cultural elites (where they are most immediately obvious), but also to the disadvantaged, and not only to the developed world but also to developing countries. And their impacts extend in two directions: Just as the engagement of IT helps shape the development of inventive and creative practices, so also can inventive and creative practices positively influence the development of IT. See Box 1.1. This report explores the complex, evolving intersections of IT with some important domains of creative practice—particularly in the arts and design—and recommends strategies for most effectively achieving the benefits of those intersections.

BOX 1.1

The Utility of Information Technology

A common answer to the question, What good is information technology?, is that it enhances productivity. Unquestionably, information technology (IT) now helps one to perform many routine tasks with greater speed and accuracy, with fewer errors, and at lower cost. So computers and software products are marketed as productivity tools, investments in IT are justified in terms of productivity gains, and economists try (sometimes without success) to measure those gains. In this role, IT is a servant.

An additional claim, which can be justified in certain contexts, is that IT enhances the quality of results. Laser-printed documents not only are quicker and cheaper to produce than handwritten or typewritten ones but may also be crisper and more legible. The outputs of detailed computer simulations of systems may be more reliable, and more useful to engineers, than the approximate, rule-of-thumb hand calculations that were used in earlier eras. And a sophisticated optimization program may produce a better solution to an allocation problem than manual trial and error. In this role, IT supports creative craftsmanship.

A still stronger, but frequently defensible, claim is that IT enables innovation—the production of outcomes that would otherwise simply not be possible. Scientists may use computers to analyze vast quantities of data and thereby derive new knowledge that would not be accessible by other means. Architects may use curved-surface modeling and computer-aided design/manufacturing systems to design and build forms that would have been infeasible—and probably would not even have been imagined—in earlier times. And new, electronic musical instruments, which make use of advanced sensor and signal-processing technology, may open up domains of composition and performance that could not be explored using traditional instruments. In this role, IT becomes a partner in processes of innovation.

Perhaps the strongest claim is that IT can foster practices that are creative in the most rigorous sense—scholarly, scientific, technological, design, and artistic practices that produce valuable results in ways that might be explained in retrospect but could not have been predicted. At this point, one might detect a whiff of paradox—a variant on Plato's famous *Meno* paradox. Unless it offers users a means to produce something they already know they want, IT is not helpful. But if someone produces something merely by running a program, the production process is predetermined and potentially standardized, so how can the result be truly creative?

INVENTIVE AND CREATIVE PRACTICES

Creativity is a bit like pornography; it is hard to define, but we think we know it when we see it.[1] The complexities and subtleties of precise definition should not detain us here, but it is worth making a few crucial distinctions.

Certainly, creative intellectual production can be distinguished from the performance of routine (though perhaps highly skilled) intel-

[1]For a concise summary of attempts to define creativity within a variety of intellectual traditions, see Carl R. Hausman, 1998, "Creativity: Conceptual and Historical Overview," pp. 453-456 in *Encyclopedia of Aesthetics*, Vol. 1, Michael Kelly, ed., Oxford University Press, New York.

lectual tasks, such as editing manuscripts for spelling and grammar, or applying known techniques for deriving solutions to given mathematical problems. Less obviously, creativity can be distinguished from innovation; there are plenty of software products and business plans that are (or were) innovative, in the sense of accomplishing something that had not been attempted before, without being particularly creative. And there are many original scientific ideas that turn out to be wrong. There is always something unexpected, compelling, and even disturbing about genuinely creative production.[2] It claims value, and it has an edge. It challenges our assumptions, forces us to frame issues in fresh ways, allows us to see new intellectual and cultural possibilities, and (according to Kant, at least) establishes standards by which future work will be judged.[3]

The implicit and explicit ambitions reflected in creative production tend to differentiate it from routine production. It often focuses on unexpected questions rather than those that have already entered the intellectual mainstream. It goes for high payoffs and is undeterred by accompanying high risks. It seeks out big questions rather than opportunities to make incremental advances, and it looks for fundamental change. It is not bothered by rule breaking, boundary crossing, and troublemaking. And it is characteristically reflexive—engaged in reflecting upon and rethinking processes, not just applying them.

There is always something unexpected, compelling, and even disturbing about genuinely creative production.

Creative production is not always positive and widely valued; one can be creatively evil, and one can waste creative talents on crazy projects that nobody cares about. But the products of creative science, scholarship, engineering, art, and design—even creative basketball—can bring immense benefits to society, as well as providing deep satisfaction to their originators. So respect is accorded to creative individuals and institutions, and society is often willing to invest in projects and programs that plausibly promise (though can never quite guarantee) creative results.

For Plato, and later for the Romantics, creativity was an ineffable attribute of certain mysteriously favored individuals—a gift of the gods. You could cultivate and exercise it if you had it, but there wasn't much else you could do about it. Today's consensus (endorsed by this Committee on Information Technology and Creativity) favors the view that creativity can be developed through education and opportunity,

[2]Hausman ("Creativity," 1998, p. 454) puts the point more technically, as follows: "Not just anything brought into being invites us to call it a creation, however. There is a stronger or radical and normative expectation that what is brought into being regarded as having *newness* and (at least for the creator) *value*. The newness of the outcome of such a radical creative act is a characteristic not simply of another instance of a known class—a numerical newness, such as may be attributed to a freshly stamped penny or a blade of grass that has just matured—but an instance of some new kind. It is a thing that is one of its kind that occurs for the first time, and being thus newly intelligible, is valuable."

[3]Immanuel Kant, 1781, *Critique of Pure Reason*. See <http://www.arts.cuhk.edu.hk/Philosophy/Kant/cpr>. Note that as this report went to press, all URLS cited were active and accessible.

that it can be an attribute of teams and groups as well as individuals, and that its social, cultural, and technological contexts matter. The committee tends to believe that it is possible to identify and establish the conditions necessary for creativity, and conversely, that we risk stifling creativity if we get those conditions wrong. Renaissance Florence clearly provided the conditions for extraordinary artistic and scientific creativity, but it is easy to name many modern cities (we will avoid getting ourselves into trouble by doing so) that apparently do not.

More precisely, creative practices—practices of inquiry and production that seek more than routine outputs and aim instead for innovative and creative results—can be encouraged and supported in some very concrete and specific ways. Society can try to provide the tools, working environments, educational preparation, intellectual property arrangements, funding, incentives, and other conditions necessary to support creative practices in various fields.

DOMAINS AND BENEFITS OF CREATIVITY

No intellectual domain or economic sector has a monopoly on creativity; it manifests itself (often unpredictably) in multiple fields and contexts. But the manifestations vary in form and character, in associated terminology, and in the types of benefits that result.

In science and mathematics, the most fundamental outcome of creative intellectual effort is important new knowledge. Generally, scientists and mathematicians are clear on the difference between such knowledge and that which results from incremental advances within established intellectual frameworks. Ground-breaking discovery is widely (though not universally) regarded as a product of great value in itself, but it is also valued more pragmatically—as an enabler of technological innovation.

In engineering, and in technology-based industry, creativity yields technological inventions. Such inventions can result in commercially successful products, in improvements to the quality of life (as, for example, when motion picture technology enabled a new form of entertainment, or when an innovative new drug provides a cure for a disease), and in the generation of income streams through intellectual property licensing arrangements. Thus the social and economic benefits are often clearly identifiable and measurable. In recent decades, information technology has been a particular locus of technological invention, the benefits of which need no elaboration here.[4]

[4]For an elaboration, see Computer Science and Telecommunications Board, National Research Council, 1999, *Funding a Revolution: Government Support for Computing Research*, National Academy Press, Washington, D.C.

An important manifestation of economic creativity is entrepreneurship—bringing together ideas, talent, and capital in innovative ways to create and make available products and services. Often, in fields such as information technology and biotechnology, close alliances emerge between the institutions of technological innovation (e.g., research universities) and entrepreneurial activity; each one requires and motivates the other. This is particularly evident in fast-moving, high-tech economic clusters, such as the information technology cluster in Silicon Valley or the biotechnology cluster of Cambridge, Massachusetts.

Cultural creativity manifests itself in the production of works of art, design, and scholarship. Like contributions to scientific and mathematical knowledge, such works are highly valued in themselves. Nations and cities take immense pride in their major cultural figures, their cultural institutions, and their cultural heritage. Many value the experience of producing as well as consuming art, design, and scholarship. Not only high cultural practices, such as opera at the Metropolitan in New York City, but also popular practices, such as amateur photography, may be valued for the participant experiences they provide.

It is possible to identify and establish the conditions necessary for creativity, and conversely, we risk stifling creativity if we get those conditions wrong.

Practices of cultural creativity also provide the foundation of the so-called creative industries that seek profits from production, distribution, and licensing.[5] One component of the creative industries consists of economic activity directly related to the world of the arts—in particular, the visual arts, the performing arts, literature and publishing, photography, crafts, libraries, museums, galleries, archives, heritage sites, and arts festivals. A second component consists of activity related to electronic and other newer media—notably broadcast, film and television, recorded music, and software and digital media. And a third component consists of design-related activities, such as architecture, interior and landscape design, product design, graphics and communication design, and fashion.

There are some problems with the very idea of "creative" industries. Creativity clearly is not confined to them, and much of what they engage in could hardly be called creative in any sense. Sometimes, as when they devote their efforts to churning out routine "content," they even seem actively counter-creative. Still, the creative industries do ultimately depend on talented, original artists, designers, and performers to create the value that they add to and deliver, while many artists, designers, and performers depend on the infrastructure of the creative industries and are rewarded by their engagement with the creative industries. The idea is problematic in some respects and there-

[5]The U.K. Creative Industries Taskforce, in its 1998 report *Creative Industries Mapping Document*, defined the creative industries as "those industries which have their origin in individual creativity, skill and talent and which have the potential for wealth and job creation through the generation and exploitation of intellectual property." See <http://www.culture.gov.uk/creative/creative_industries.html>.

fore should be treated with appropriate critical caution, but it remains a useful one. And, in any case, the name "creative industries" has stuck.

THE CREATIVE INDUSTRIES

That the creative industries are now big business hardly needs emphasis. There have been numerous recent efforts to quantify this intuition by measuring their economic contributions. According to an estimate developed by Singapore's governmental Workgroup on Creative Industries,[6] the United States led the way in the creative industries in 2001, with the creative industries accounting for 7.75 percent of the gross domestic product (GDP), providing 5.9 percent of national employment, and generating $88.97 billion in exports,[7] with the United Kingdom, Australia, and Singapore also exhibiting industry sectors of significant size (representing 5.0 percent, 3.3 percent, and 2.8 percent of national GDP, respectively).[8]

The United States has some important, major creative industry clusters,[9] notably those of Los Angeles (with a particular emphasis on film, television, and music), New York (with a particular emphasis on publishing and the visual arts), San Francisco (with particular recent emphasis on digital multimedia), and some smaller, more specialized clusters in cities such as Boston, Austin, and Nashville. In Europe, many creative industry clusters, such as those of London, Paris, and Milan, have developed at long-established centers of culture. In Australia, significant new clusters, based mostly on film, television, and digital multimedia, have emerged in Sydney, Melbourne, and Adelaide. A cluster oriented toward software tools and production has developed in Canada, especially in Toronto and Montréal. The value of such clusters is obvious, so it is not surprising that there has been growing worldwide interest in the regional development strategy of

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[6]Workgroup on Creative Industries, 2002, *Creative Industries Development Strategy: Propelling Singapore's Creative Economy*, Singapore, September, p. 5.

[7]For core copyright industries only.

[8]These numbers represent the percentages of GDP for different years between 1997 and 2001, though the fundamental point remains valid—the creative industries represent a significant segment in each nation's economy. See Economic Review Committee, Government of Singapore, 2002, "The Rise of the Creative Cluster," *Creative Industries Development Strategy*, p. 5. Available online at <http://www.erc.gov.sg/pdf/ERC_SVS_CRE_Chapter1.pdf>.

[9]Industry clusters are often defined as "concentrations of competing, collaborating and interdependent companies and institutions which are connected by a system of market and non-market links" (see definition of the Department of Trade and Industry, United Kingdom, available online at <http://www.dti.gov.uk/clusters/>).

encouraging creative industry clusters.[10] In the United Kingdom, for example, each of the ten Regional Development Agencies has focused on the creative industries as a growth sector, and each local authority is mandated by the Department of Culture, Media and Sport to produce a development strategy for the creative industries.[11]

It is important to recognize that these creative clusters do not just consist of large firms. They also encompass independent artists and designers, numerous small businesses, cultural institutions such as galleries and performing arts centers, and educational institutions. Many of those involved with the creative industries may play multiple roles; for example, artists and designers may combine independent practice with teaching, and employees of large firms may "moonlight" with small practices of their own.

Creative clusters encompass independent artists and designers, numerous small businesses, cultural institutions such as galleries and performing arts centers, and educational institutions.

But the creative industries also have a strategic importance that extends beyond regional economic development. In a progressively interdependent world where culture tempers and inflames politics as well as markets, strong creative industries are a strategic asset to a nation; the predominance of Hollywood movies, Japanese video games, and Swiss administration of FIFA soccer are forms of soft power that have global, albeit subtle, effects, particularly in countries whose bulging youth populations have access to television and the Internet. Movies, music videos, fashion, and design foster aspirations in the developed and developing world. It matters that teenagers in China—or Pakistan—idolize Michael Jordan. The ability to generate a cultural agenda via the arts, design, or media is a form of deep, pervasive influence and is as integral to global leadership as trade policy or diplomatic relationships.[12] Globally available cultural products serve as a kind of common social currency in an increasingly fractured and fractious world. To that extent, the reach and robustness of a nation's creative practices can constitute a form of global leadership—while also, of course, potentially attracting charges of cultural imperialism. A nation's creative practices can also provide valuable visibility and branding, as with Italian and Finnish design.

[10]See Chapter 7 for further discussion.

[11]See Department of Culture, Media and Sport, Creative Industries Program, 2000, *Creative Industries: The Regional Dimension*, Report of the Regional Issues Working Group, February. Available online at <http://www.culture.gov.uk/creative/index.html>.

[12]See Shalini Venturelli, 2001, *From the Information Economy to the Creative Economy: Moving Culture to the Center of International Public Policy*, Center for Arts and Culture, Washington, D.C., available online at <http://www.culturalpolicy.org/pdf/venturelli.pdf>; and Joseph S. Nye, 1999, "The Challenge of Soft Power: The Propounder of This Novel Concept Looks at Lloyd Axworthy's Diplomacy," *Time*, February 22, available online at <http://www.time.com/time/magazine/intl/article/0,9171,1107990222-21163,00.html>.

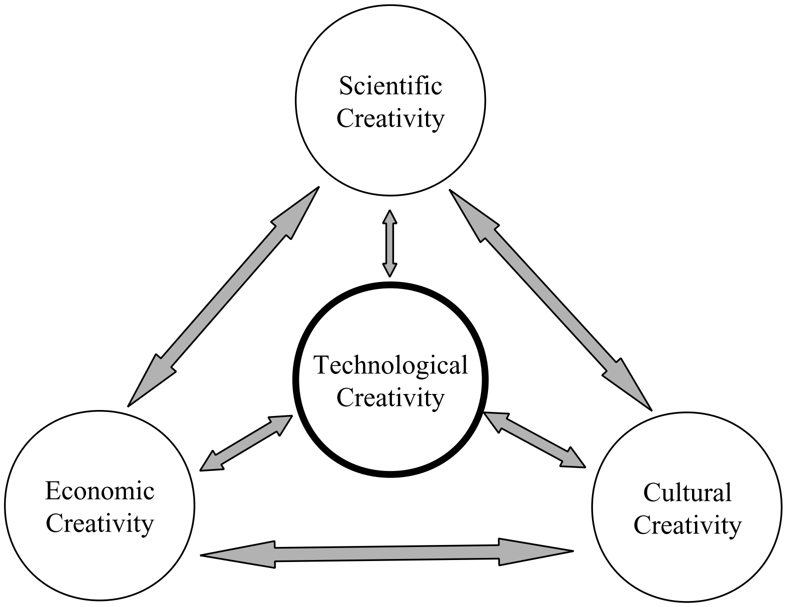

FIGURE 1.1 Domains of creative activity.

INTERACTIONS AMONG DOMAINS OF CREATIVE ACTIVITY

For some purposes it is useful to distinguish scientific, technological, economic, and cultural creativity, as discussed above. But it is also important to emphasize that these domains are often tightly coupled, and that activity in one may depend on parallel activities in others. This committee was charged and constituted to focus primarily on creative practices in the arts and design, and their intersections with information technology, but it recognized that the coupling to other domains of creative practice could not be ignored.

Figure 1.1 illustrates the approximate nature of that coupling—each broad domain of creative practice in two-way interaction with every other. Reflecting a National Academies/Computer Science and Telecommunications Board perspective, technological creativity is shown at the center of the diagram, which of course could also be redrawn to show any of the other domains at the center.

Consider, for example, some important interactions of technological creativity with other domains. Scientific discovery sometimes drives technological invention, but conversely, the pursuit of technological innovation often suggests scientific questions and ideas. Similarly, entrepreneurial energy may motivate engineering and product innovations, but such innovations may also demand creative strategies for successfully bringing inventions to the market. And newly invented technologies may produce bursts of artistic and design creativity—as with Renaissance perspective, photography, film, radio, television, and computer graphics—while the work of artists and designers may generate desire for technological innovations, shape the directions of technological investigations, and provide critical perspectives.

The additional reciprocal relationships indicated by Figure 1.1 are no less worthy of note. In the creative industries, innovative entrepreneurs develop new ways to produce and distribute creative products, while creative production often demands of businesses and institutions (such as museums, cultural foundations, and art and design schools) new distribution, curatorial, preservation, and other strategies. There is a subtle, complex, but undoubtedly important (in some periods, at least) relationship between the intellectual frontiers of the creative arts and the sciences. And there are even cross-relationships between scientific and economic innovation—as when physics Ph.D.s moved to Wall Street and brought with them new tools and methods for the financial industry.[13]

Innovative design is often situated precisely at the intersection of technologically and culturally creative practices. On the one hand, designers are frequently avid to exploit technological advances and to explore their human potential. On the other, they typically have close intellectual alliances with visual and other artists. And innovative design can yield high economic payoffs; firms such as Apple, Sony, Audi, and Target have differentiated themselves and in some cases turned themselves around through innovative design. Volkswagen remade its image, and refreshed its reputation for witty innovation, with the revived and redesigned Beetle. Bilbao put itself on the world map by building the highly innovative Bilbao Guggenheim Museum—a work that embodies many technological innovations and at the same time is engaged with the frontiers of the visual arts. South Korea has recently had great success with a national policy of emphasizing quality and innovation in the design of consumer products.

Innovative design is often situated precisely at the intersection of technologically and culturally creative practices.

These various interrelationships suggest the importance not only of specialized loci of creativity, such as highly focused research laboratories and individual artist's studios, but also of creativity clusters—complexes of interconnected activity, encompassing multiple domains, which provide opportunities and incentives for productive cross-fertilization. Thus a laboratory director might seek to establish a creative, cross-disciplinary cluster of individuals and research groups at the scale of a small organization; a research university provost might seek a creative cluster of departments, laboratories, and centers at the scale

[13]See, for example, "Physicists Graduate from Wall Street," *The Industrial Physicist*, December 1999, available online at <http://www.aip.org/tip/INPHFA/vol-5/iss-6/p9.pdf>.

of a campus; regional planners might try to encourage formation of creative industrial and institutional clusters within their jurisdictions; and national strategists might seek to do so at even larger scales.

The importance of such efforts is increasingly widely recognized, and a related research and policy literature is emerging: Economists explore the proposition that "economic growth springs from better recipes, not just from more cooking"—that is, from the generation and application of innovative and creative ideas;[14] planners analyze "creative cities" and "creative regions" that attract and retain talent, and that provide environments in which creative practices flourish;[15] the idea of a "creative class" has quickly become popular;[16] and the possibility of shifting from "the information economy" to "the creative economy" has become a hot topic among policy makers from Scotland to Hong Kong.[17]

THE ROLES OF INFORMATION TECHNOLOGY

Figure 1.2 shows a more specialized version of Figure 1.1, in which information technology replaces technological creativity at the center. Information technology has important relationships to creative practices in other domains. It benefits enormously from basic scientific and mathematical advances, and in return, it provides scientists and mathematicians with powerful new tools and methods. It provides entrepreneurs with a stream of opportunities to develop and market new products and services, while benefiting from the research and development investment that the prospect of successful commercialization motivates. It provides artists and designers with whole new fields of creative practice, such as computer music and digital imaging, together with tools for pursuing their practices in both new and established fields, while benefiting from the inventive and critical insights that artists and designers can bring to it. Increasingly, the committee suggests, information technology constitutes the glue that holds clusters of creative activity together.

The effectiveness of information technology as glue is enhanced by its extraordinary capacity to apply the same concepts and techniques across many different fields. Once content is reduced to bits, it doesn't much matter whether it represents text, music, scanned im-

[14]See Paul M. Romer, 1993, "Economic Growth," *The Fortune Encyclopedia of Economics*, David R. Henderson, ed., Warner Books, New York.

[15]See Charles Landry, 2000, *The Creative City: A Toolkit for Urban Innovators*, Earthscan, London.

[16]See Richard Florida, 2002, *The Rise of the Creative Class*, Basic Books, New York.

[17]See John Howkins, 2002, *The Creative Economy: How People Make Money from Ideas*, Penguin Books, London.

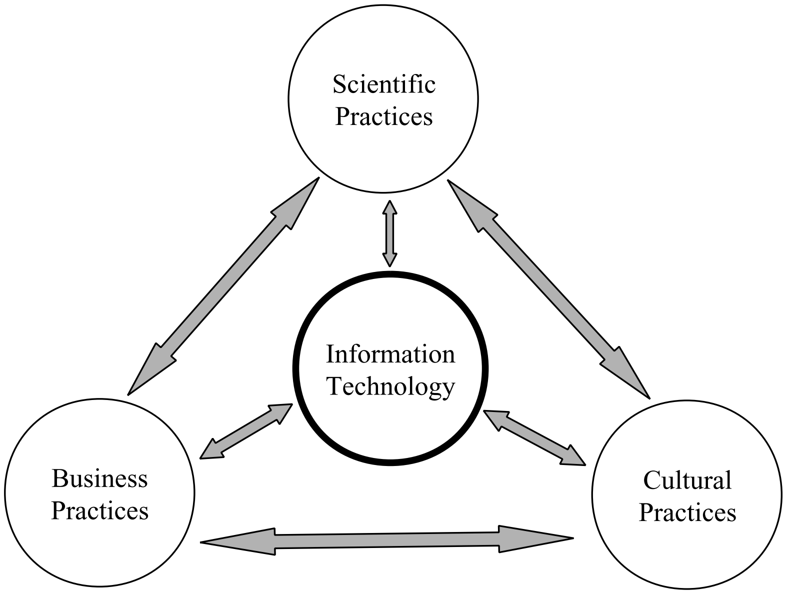

FIGURE 1.2 Information technology as glue.

ages, three-dimensional (3D) computer-aided design (CAD) models, video, or scientific data; the same techniques, devices, and channels can be used for storing and transporting it. Once you have a stream of digital data, whatever the source, you can apply the same techniques to process it. Once you have an efficient sorting algorithm, you can use it to order vast files of scientific data or to arrange polygons (digital objects) for hidden-surface removal in rendering a 3D scene. Once you have a library of software objects, you can use those objects as building blocks to quickly construct specialized software tools for use in many different domains.

Furthermore, information technology can support the formation of non-geographic clusters of creative activity. In the past, such clusters depended heavily on geographic proximity for the intense face-to-face interaction and high-volume information transfer that they required. (If you were in the movie business you wanted to be in Hollywood, if you were in publishing you wanted to be in New York, and so on.) Distance is not dead, and these things still matter, but efficient digital telecommunication now supports new types of clusters. Architectural projects, for example, are now routinely carried out by geographically distributed team members who exchange CAD files over the Internet and meet by videoconferencing—with the advantage that specialized talent and expertise can be drawn from a global rather than local pool. Long-distance electronic linkages between local clusters, such as that between the film production cluster in Hollywood and the postproduction cluster in London's Soho, are also becoming increasingly important.

And the growing integration of digital storage and processing technology with networking technology and sensor technology is even further strengthening the role of information technology as glue. In many domains, cycles of production, distribution, and consumption can now be end-to-end digital. For example, the production and distribution of a photographic image used to entail a silver-based chemical process for capture, half-toning followed by a mechanical process to print large numbers of copies, and physical transportation to distribute those copies; now, capture can be accomplished by means of a charge-coupled device (CCD) array in a digital camera, replication becomes a matter of applying software to copy a digital file, and distribution through the global digital network can follow instantly.[18]

Finally, many argue that information technology is, by its very nature, a powerful amplifier of creative practices. Because software can readily be copied and disseminated, and because there can be an unlimited number of simultaneous users, software supports the dissemination, application, and creative recombination of innovations on a massive scale—provided, of course, that intellectual property arrangements do not unduly inhibit creative work. Much of the current debate about intellectual property and information technology focuses on questions of how best to support, encourage, and reward creative practices.[19]

Many argue that information technology is, by its very nature, a powerful amplifier of creative practices.

In summary, information technology now plays a critical role in the formation and ongoing competitiveness of clusters of creative activity—both geographic clusters and more distributed clusters held together by electronic interconnection and interaction. IT is an important driver of the expanding creative industries. And, due to several factors, its role as glue is strengthening. First, the generalizability of digital tools and techniques across multiple domains makes them particularly efficient and effective in this role; they can displace predigital tools and techniques, as in the cases of CAD displacing drawing boards and drafting instruments and digital imaging displacing silver-based photography. Second, the increasingly effective integration of diverse digital technologies is producing efficient, large-scale, multipurpose production and distribution systems that can effectively serve the creative industries. Third, these systems support the formation of non-geographic clusters of creativity that can draw on global talent pools. And finally, the amplification effects that are inherent to information technology are likely to have strong (sometimes unexpected) multiplier effects; they may unleash waves of scientific and mathematical, technological, economic, artistic, and cultural creativity.

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[18] CCD arrays consist of tiny light sensors that encode scenes as sets of intensity values. The larger the array, the finer the resolution of the picture. The development of digital cameras has been driven, generation by generation, by the release of successively larger CCD arrays.

[19] See Chapter 7 for an articulation of the important role played by intellectual property issues in information technology and creative practices.

THE RACE FOR CREATIVITY IN A NETWORKED WORLD

It seems to this committee that there is an emerging, global race to establish effective, sustainable clusters of IT-enabled creative activity at local, regional, and national scales—and at even larger scales, like that of the European Union. A number of studies and initiatives are directed at this goal, such as the Seoul Digital Media City project (South Korea),[20] the BRIDGES International Consortium on Collaboration in Art and Technology (Canada),[21] the Massachusetts Museum of Contemporary Art (United States), the Kitchen's national art and technology network (United States),[22] and the National Endowment for Science, Technology and the Arts (United Kingdom).[23] The rewards are high; such clusters are engines of economic growth, of enhanced quality of life, and of cultural and political influence—that is, of soft power. Success in launching and sustaining them depends on capacity to attract and retain creative talent, on establishing the conditions and incentives necessary for that talent to flourish, and—increasingly—on the effective exploitation of information technology.

In the following pages, the committee focuses specifically on clusters of creative activity in the arts and design and their interactions with information technology, as illustrated in Figure 1.3—which is simply a subset, but a crucial one, of Figure 1.2. The interactions between these two domains are important not only for their mutually beneficial effects, but also because they help to energize larger systems of interconnected creative activity. This report provides more detailed analyses of the conditions needed for creativity in a networked world and recommends strategies for establishing and sustaining successful clusters of IT-related creative activity in the arts and design. It asks the following questions:

1. How can information technology open up new domains of art and design practice and enable new types of works?
2. How can art and design raise important new questions for information technology and help to push forward research and product development agendas in computer science and information technology?

[20]See <http://www.dmc.seoul.kr/english/why/overview.jsp>.

[21]See <http://www.banffcentre.ca/bnmi/bridges/>.

[22]See <http://www.thekitchen.org>.

[23]Additional information about the Massachusetts Museum of Contemporary Art and other initiatives is given in Chapters 7 and 8.

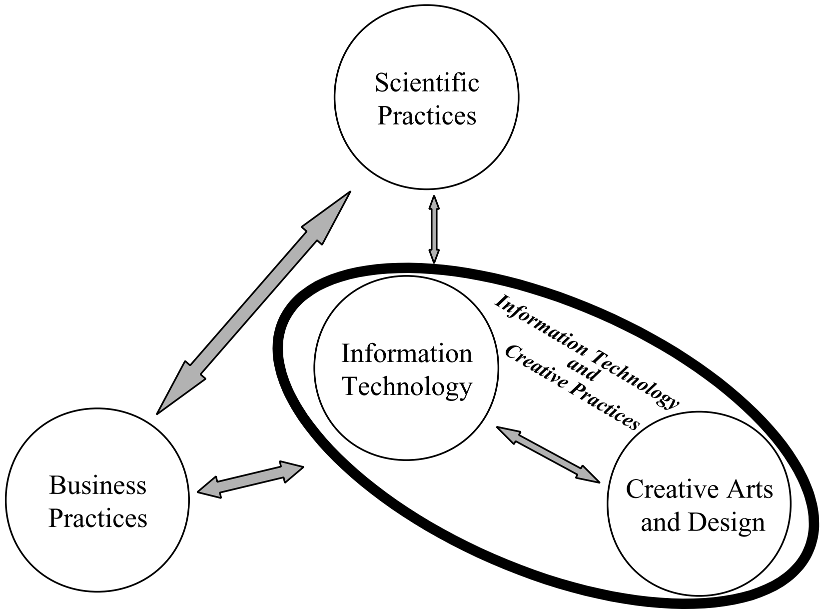

FIGURE 1.3 Information technology and creative practices.

3. How can successful collaborations of artists, designers, and information technologists be established?

4. How can universities, research laboratories, corporations, museums, arts groups, and other organizations best encourage and support work at the intersections of the arts, design, and information technology?

5. What are the effects on information technology and creative practices work of institutional constraints and incentives, such as intellectual property arrangements, funding policies and strategies, archiving, preservation and access systems, and validation and recognition systems?

ROADMAP FOR THIS REPORT

This chapter provides an introduction to the world of information technology and creative practices (ITCP) and outlines the benefits to the economy and society from encouraging and supporting work in this new domain. Chapter 2 explores the systemic nature of creativity and how multiskilled individuals and collaborative groups pursue work. Various factors, from differences in communication style and vocabulary to evolving work environments, influence how this work is carried out. Information technology is the focus of Chapters 3 and 4.

Chapter 3 analyzes the role of IT in supporting ITCP work and offers observations for the future design of improved IT tools that would provide better support of ITCP. This role for IT—in service to other disciplines—is a well-appreciated one. Chapter 4 challenges this traditional role to consider how the art and design influences of ITCP can help to advance the discipline of computer science. Chapters 5 and 6 discuss the venues for conducting, supporting, and displaying ITCP work. A wide range of venues—from specialized centers for ITCP to museums and corporations—is explored in Chapter 5; ITCP-related programs and curricula in schools, colleges, and universities are covered in Chapter 6. Institutional and policy issues such as intellectual property concerns, digital archiving and preservation, validation and recognition structures, and regional planning are presented in Chapter 7. In Chapter 8, the policies and practices for funding ITCP work are described and analyzed. The discussions from the chapters are synthesized and findings and recommendations are articulated in the report's opening "Summary and Recommendations" chapter. Although these findings and recommendations are directed to particular decision makers such as university administrators, officers of funding agencies, or directors of cultural institutions, many of the ideas are applicable to multiple decision makers, given that ITCP transcends current institutional, disciplinary, and professional boundaries.

2 Creative Practices

People are the engines of creative practice. To work within the realm of information technology and creative practices (ITCP), individuals or groups need to be fluent in multiple disciplines. Some individuals can simultaneously master multiple subject domains (modern-day Leonardo da Vincis) as required, whereas others participate in collaborative groups of people with complementary or synergistic expertise and skills. Each approach presents its own set of advantages and challenges. Each approach also benefits from resources such as training tools and suitable working conditions. This chapter explores how human creative capabilities can be accessed, developed, and applied to ITCP work.

The first section briefly reviews what it means to be fluent in the ITCP context and outlines the role that individuals and groups with such abilities play in producing ITCP work. The second section discusses, and explores how institutions might enhance, the two basic approaches to work in ITCP: individuals alone (e.g., an independent artist), and collaborative groups of various types (e.g., a team developing a video game). The third section discusses key challenges that arise in cross-disciplinary collaborations. The final section outlines resources that can support the human capability to create meaningfully.

WHAT MAKES PEOPLE CREATIVE

What makes one action ordinary and another creative? Part of the answer is personality, although there has been surprisingly little study of creativity by psychologists.[1] Research points to a tendency for

[1]A survey of psychological research on creativity, intended to motivate more attention, can be found in Dean Keith Simonton, 2000, "Creativity: Cognitive, Personal, Developmental, and Social Aspects," *American Psychologist* 55(1): 151-158.

creative people "to be independent, nonconformist, unconventional, even bohemian, and . . . to have wide interests, greater openness to new experiences, a more conspicuous behavioral and cognitive flexibility, and more risk-taking boldness."[2] Part of the answer is behavioral, including the extent to which deliberation and skill are involved. Deliberation involves making choices about things that matter. "Fasting," Nobel laureate Amartya Sen has famously written, "is not the same thing as being forced to starve. Having the option of eating makes fasting what it is: choosing not to eat when one could have eaten."[3] Other factors relate to context, such as the nature of one's experiences, notably "(a) diversifying experiences that help weaken the constraints imposed by conventional socialization and (b) challenging experiences that help strengthen a person's capacity to persevere in the face of obstacles"[4]—both of which are characteristic of an emergent field in general and ITCP in particular. Interestingly, a factor in achieving diversifying and challenging experiences may be cultural diversity; there is evidence that exposing a culture to alien influences and experiencing marginality or even dissent are correlated with creativity.[5] More generally, the start of a creative act is the escape from one range of assumptions—a context—often with the aid of another context seemingly at odds with the first but that provides a new way of viewing what we already thought we understood. The arts do this for IT, and IT does this for the arts.[6]

Creativity can be linked to tools, which have been a constant factor in the arts as well as in science and engineering. Because ITCP is defined with reference to a set of tools—IT—it calls for an understanding of creativity as human complements to digital capabilities: the opportunity, knowledge, and skill to make disciplined judgments about how and when to use or not use those capabilities. Although novices can now enter many fields through interfaces—provided by software packages—that encapsulate and parameterize aspects of specialized trades and crafts that previously took lifetimes to learn, learning to use a tool does not of itself make one a skilled practitioner.

There is a difference between basic functional know-how (e.g., knowing a few words of a foreign language) and higher-level skill, or

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[2]Simonton, 2000, "Creativity," p. 153.

[3]Amartya Sen, 1999, *Development as Freedom*, Alfred A. Knopf, New York, p. 75. The committee is indebted to Mansell (2001) and Garnham (1997) for their readings of Sen in terms of communication and media policy. See Robin Mansell, 2001, "New Media and the Power of Networks," First Dixons Public Lecture, London, October 23, available online at <http://www.lse.ac.uk/Depts/Media/rmlecture.pdf>; and Nicholas Garnham, 1997, "Amartya Sen's 'Capabilities' Approach to the Evaluation of Welfare: Its Application to Communications," *Javnost-The Public* 4(4): 25-34.

[4]Simonton, 2000, "Creativity," p. 153.

[5]Simonton, 2000, "Creativity," p. 155.

[6]Allucquère Rosanne Stone, in *The War of Desire and Technology at the Close of the Mechanical Age* (MIT Press, Cambridge, Mass., 1995), describes how technology can provide prostheses, expanding and enhancing one's interaction with the world.

fluency.[7] Previous studies of fluency in the use of IT have distinguished between general intellectual capabilities; IT-specific but device-independent generic concepts; and a more contingent class of specific, device-dependent technical skills. In *Being Fluent with Information Technology*,[8] important generic IT conceptual capabilities are identified, including algorithmic thinking, facility with principles of knowledge representation, and adaptability to change.[9] These conceptual capabilities represent a level of understanding that goes far beyond how to use a given software package. Relatively few artists may pursue true IT fluency, since artists usually learn what they need to know, appropriate the necessary technology and materials, and make their art, but some movement in that direction appears important for ITCP.[10]

Relatively few artists may pursue true IT fluency, but some movement in that direction appears important for ITCP.

Early ITCP has been associated with artists' frustrations with IT, and ease of use for non-technically expert or non-fluent artists and designers is a concern. Yet highly creative performance by artists and designers has been associated with tools that are somewhat difficult to use,[11] especially when the alternative is ease of use achieved through preprogrammed and therefore limiting or constraining features. Creative people always struggle against the limits of their medium—wood splits, musical instruments have limits to pitch and volume, and so on. The challenges presented by IT have helped to stimulate some kinds of art and design—and artists' responses to those challenges, from seeking better tools to exploiting the flaws in or breaking those available as part of their art, should help to stimulate development of new forms of IT.

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[7]An emphasis on individual talent and resourcefulness is, of course, commonplace in the traditional arts. A novice musician can pick up an instrument and make sounds. Skilled musicians, though, can make bad instruments sound sweet, and they alone have the virtuosity to "possess" great ones.

[8]Computer Science and Telecommunications Board, National Research Council, 1999, *Being Fluent with Information Technology*, National Academy Press, Washington, D.C.

[9]Paul David, in a similar vein, discusses the importance of generic learning abilities, which must go beyond the acquisition of a specific repertoire of techniques, or even the ability to cope with a need for constant updating of technical knowledge, to a "capacity to understand and anticipate change." See Paul David and Dominique Foray, 2002, "An Introduction to the Economy of the Knowledge Society," *International Social Science Journal (UNESCO)* 171:9.

[10]When artists try to learn skills for their art they are very well motivated. They see the skills as a way to do an excellent job, to do exciting work (they like the results), and to distinguish themselves from other artists. They may become interested in the intrinsic qualities of the IT, but this is more unusual. (Bill Alschuler, California Institute of the Arts, 2002, personal communication.)

[11]Of course, artists and designers do not like more difficult tools per se. Instead, the committee is acknowledging the usual tradeoff between flexibility and advanced features with preprogrammed solutions and ease of use. For Harold Cohen, artists' tools and instruments have to be "difficult enough to stimulate a sufficient level of creative performance, and you don't do that with something that's easy to use." For further discussion of this point, see Chapter 3 in Pamela McCorduck, 1990, *Aaron's Code: Meta-Art, Artificial Intelligence, and the Work of Harold Cohen*, W.H. Freeman, New York.

When people or groups are fluent in IT and arts and design disciplines, they may work at either of two intersections of information technology and creative practices. The first involves the use of computational technologies as a medium for cultural practices (i.e., viewing IT as providing tools in support of the arts and design fields), stressing the continuities between IT and older technologies and the need for a malleable cultural informatics[12] that remains attuned to traditional practices such as reading, singing, painting, or dancing. The second stresses art as a form of research or knowledge production that is interwoven with the practice of research in IT. There is a lot happening at both intersections, and, despite their superficial differences, the intersections are synergistic and might even be described as flip sides of the same phenomenon. These intersections serve as the bases for the committee's examination in Chapters 3 and 4.

When people or groups are fluent in IT and arts and design disciplines, they may work at either of two intersections of information technology and creative practices.

In seeking to understand ITCP and the people who do this work, the committee found it useful to examine not only the content of the work involved, but also the details of how it is organized, both socially and institutionally. As is further discussed in Chapters 5 and 6, distinctive new institutional structures have appeared over the past century, combining studio or atelier creation with research-oriented knowledge production in educational, cultural, scientific, and business contexts. All these institutional contexts attempt to balance and support a variety of interests simultaneously. This hybridity is apparent in the shifting roles individuals play both alone and in teams in such settings, be it as artist, designer, researcher, theoretician, entrepreneur, or technician. A similar hybridity was also evident in the artifacts that the committee considered best to exemplify the intersections of IT and creative practice—rather than material objects, they tended to be processes (e.g., interactive works) with social and material aspects, which span boundaries and can be understood in different ways depending on social context.

These observations correspond closely to the social model of creativity proposed by Mihaly Csikszentmihalyi. In this model, creativity is a three-part social system made up of individuals (or groups of individuals), knowledge domains, and institutional structures. As illustrated in Figure 2.1, *individuals* (or groups) produce new variations on inherited conventions stored in *domains*. These novelties are promoted or filtered in the *field* of social institutions, which select the genres, theories, and technologies that become the new conventions for the continuously updated knowledge domains, and that thus are recycled to form new sources for individual creativity. The field component implies that "colleagues are essential to the realization of indi-

[12]Cultural informatics is "a practice of technical development that includes a deep understanding of the relationship between computer science research and broader culture," according to Phoebe Sengers ("Practices for Machine Culture: A Case Study of Integrating Artificial Intelligence and Cultural Theory," *Surfaces*, Vol. VIII, 1999).

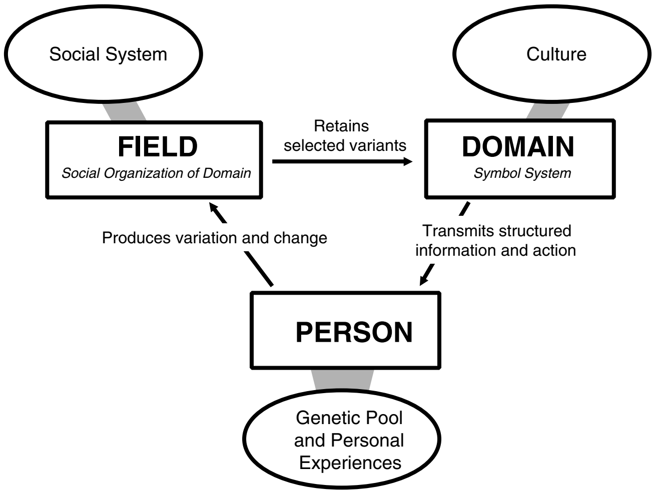

FIGURE 2.1 A systems view of creativity. This map shows the interrelationships of the three systems that jointly determine the development of a creative idea, object, or action. The individual takes information provided by the culture and transforms it, and if the change is deemed valuable by a field, it will be included in the domain, thus providing a new starting point for the next generation of creative persons. The actions of all three systems are necessary for creativity to occur. SOURCE: Derived from Mihaly Csikszentmihalyi, 1987, "A Systems Approach to Creativity," p. 326 in *The Nature of Creativity. Contemporary Psychological Perspectives,* R. Sternberg, ed., Cambridge University Press, Cambridge, U.K.

vidual creativity, . . . because creativity does not exist until those making up the field decide to recognize that a given creative product represents an original contribution to the domain."[13] (See "Validation and Recognition Structures" in Chapter 7.)

Framed in terms of this social model of creativity as a dynamic system connecting people, institutions, and knowledge domains, the creative core common to IT and the arts becomes easier to identify. Creativity results from the interaction of these three systems. And because the systems perspective underscores the importance of a community of practice to sustaining creativity, it also demonstrates the importance of understanding what it means to foster and sustain a community of practice, a goal of this report.

It may be helpful to consider an example. The work of Karim Rashid in industrial design is an illustrative case (see Box 2.1). The boundary-pushing influence of ITCP work on its fields of origin is a recurrent theme in the projects discussed in this chapter.

HOW CREATIVE PEOPLE WORK

The functional integration of the arts and design fields and IT depends on who is doing what work and how. The human resources

[13]Simonton, 2000, "Creativity," p. 155.

BOX 2.1

Information Technology and Creative Practices in an Industrial Context

Industrial design has been largely re-created by computer software, from three-dimensional computer-aided design and manufacturing (CAD/CAM) packages to databases that list new grades and alloys of metal and plastic, as well as factories themselves. Products, from automobiles to can openers, have been transformed (it is no accident that consumer goods started getting curvy and ergonomic at around the same time that buildings did). But the process of industrial design has also changed fundamentally, because the time and cost of prototyping have been radically reduced. Designers can generate multiple concept models, honing them in an iterative, evolutionary fashion. But beyond prototyping, information technology has made it possible for industrial designers to engage creatively on a different level—at the level of the manufacturing process itself.

An exemplar of this innovation is Karim Rashid, a highly acclaimed industrial designer whose work includes everything from wastepaper baskets at Bed Bath and Beyond to furniture in the New York Museum of Modern Art's design collection.[1] Rashid's experiments with product manufacturing are possible because modern mass production is increasingly mediated by software. For instance, the apparatus that produced Rashid's curving metal napkin rings for manufacturer Nambé (Figure 2.1.1) is controlled by software that regulates the circumference and length of each napkin ring. By programming the apparatus to vary these parameters randomly, within a range, Rashid was able to create thousands of unique objects, as opposed to thousands of identical objects. The idea of mass-produced one-of-a-kind products—postmodern manufacturing—is possible because one talented individual can bridge the worlds of engineering and consumer aesthetics, and because the technology exists to do so. In the process, the creative professional's role becomes more abstract. It is less about designing objects, and more about designing the process that makes the objects, including the parameters that transcend the designer's direct control. The end result conflates the uniqueness of handcraft with the scale of industrial production.

[1]Further explanation and examples of Rashid's work can be found online at <http://www.karimrashid.com>.

FIGURE 2.1.1 Napkin rings. Photo by Dick Patrick.

can be obtained through the broadening of individual skill sets and through collaborations. Some individuals involved in the arts and design are indeed expanding their knowledge and skills related to IT, and, perhaps less obviously, some computer scientists and engineers are acquiring knowledge and skills in the arts and design (there are distinctive bases in such subdisciplines as graphics and computer music). Collaborations, for all their difficulties, are frequently the preferred and sometimes the required approach, because they demand far less individual investment in learning and therefore accelerate the process of experimentation in combining different kinds of expertise (which is especially important in the early stages of exploration because of the uncertain return from investing time in learning a new area). Another factor arguing for collaboration as a stimulus is the tendency of some cross-disciplinary work, in the absence of a diverse team, to ossify within one discipline or the other. Collaborations may involve anywhere from two to hundreds of people and often are inspired and supported by non-profit organizations or commercial enterprises. Obviously, scale can change the experience and outcome of a collaboration enormously, but while it may seem obvious to suggest that "art," being associated with individuals, requires fewness, the networked nature of modern IT may change that intuition.

Many artists prefer the "move fast and travel light" style of work, which allows for a degree of independence that larger collaborative models may not always offer.

INDIVIDUALS WITH DIVERSE EXPERTISE AND SKILLS

There are some unusually talented people who can do it all, or do enough to create work that straddles more than one discipline and creates new skill sets. This approach has a unique beauty and economy; as one reviewer of this report suggested, an individual's work tends to have a conceptual wholeness, whereas collaborations may produce "camels—horses designed by committees." Many artists prefer the model of the multiskilled individual as the embodiment of the "move fast and travel light" style of work, which allows for a degree of independence in thinking and action that larger collaborative models may not always offer. People who wish to diverge from the political or aesthetic mainstream may want both complete control over their products and independence from external funding and its possible content requirements. Or they may be invested in developing a specific form of personal expression or crafting a concept or theory that they wish to determine independently. These individuals may struggle with the absence of standards in some ways but are able to make their own rules and engage cutting-edge technologies in a personal way to transform an aspect of the world.

There are many models for this style of working, ranging from individuals taking various approaches to the visual arts to novelists to the independent inventor. Growing numbers of artists are becoming skilled in software programming or hardware development, perhaps as a way to maintain a life of the imagination without interference from a client, patron, or co-worker. The acquisition of such skills is, of course, an implicit acceptance of their value to artistic pursuits. Some people, for instance, can write both computer code and music compositions or turn their code into sculpture. See Box 2.2. Such artists tend to be internally driven by artistic impulses or research interests, although they may benefit from institutional support.

One beneficiary of such support is Michael Mateas, who, at the time he described his work for the committee,[14] was a research fellow in the Studio for Creative Inquiry (an "art think tank") at Carnegie Mellon University (CMU) as well as a doctoral student in computer science.[15] Mateas combines cultural production with artificial intelligence (AI), two activities that normally have very different goals. As he described it, cultural production is interested in poetics (the negotiation of meaning between the artist and audience), artistic abstraction, and audience participation and approval, whereas AI is concerned with task competence, realism, and objectivity. He engages in "expressive AI," building novel architectures, techniques, and approaches. One of his pieces is Terminal Time, an interactive work that constructs documentary videos in real time based on both real historical events and the biases inferred from audience feedback.[16] Terminal Time encompasses a new model of ideological reasoning and a new architecture for story generation, combining the technical capabilities of IT and the dramatic story structure concepts of the arts and humanities in a novel way.[17] In Mateas's view, the project has influenced both the technical research agenda and arts practice—thus fitting nicely into the social model of creativity described above. See Box 2.3.

Individuals who wish to become proficient in multiple fields face at least two formidable challenges. One is the need to deal with enormous and increasing knowledge bases. Trying to remain up-to-date in only one field is demanding enough for most people; the 20th century witnessed tremendous growth in knowledge and a proliferation of disciplinary specialization and narrow professional certification, with a corresponding growth in support structures consisting of professional associations, conferences, periodicals, and curricula. The advent of IT, especially the Internet, has further fueled this trend, especially by facilitating communication among those with niche interests, thus promoting the establishment and maintenance of narrow specialties and interests. Even individuals who already possess both artistic and technical skills may need to learn new ones or find specialists with compatible aesthetic and intellectual views for particular projects.

Individuals who wish to become proficient in multiple fields face at least two formidable challenges: enormous and increasing knowledge bases . . . and lack of a broad institutional support structure.

[14]He briefed the committee at its January 2001 meeting held at Stanford University. See Chapter 6 for further thoughts from Michael Mateas.

[15]As discussed further in Chapter 6, CMU seems to be unusually supportive of cross-disciplinary activities.

[16]For further information about Terminal Time, see <http://www-2.cs.cmu.edu/~michaelm/>.

[17]For further discussion, see Michael Mateas, Steffi Domike, and Paul Vanouse, 1999, "Terminal Time: An Ideologically Biased History Machine," *AISB Quarterly: Special Issue on Creativity in the Arts and Sciences* 102 (Summer/Autumn):36-43.

BOX 2.2
Combining Sculpture, Software, and Hardware Skills

John Simon makes object-based sculptures that combine the skills of painting, sculpture, computer hardware construction, and software development. The work is based on algorithmically generated and intricately cut interfaces between sheets of acrylic plastic—a group of painting-like objects on a wall, with constantly changing patterns on liquid-crystal display (LCD) screens mounted on a structure that is a cross between a painting and a sculpture. See Figure 2.2.1. The software varies the patterns on the screen so that they never repeat. The "painting" is constantly new and constantly changing. Simon's work is in the collection of the Solomon R. Guggenheim Museum and the Print Collection at the New York Public Library.

Simon on his approach and motivation:

> I take the screen and the processor from mostly used laptop computers, which I get from eBay or dealers. I am currently using Apple G3 Powerbooks with 14.1-inch screens. I remove the case and mount the LCD screen to a plastic housing of my own design. The CPU [central processing unit] is mounted on the back of the housing. I install my own software, which runs automatically when the computer is turned on. The images on the screen are constantly changing. This is a way to write software directly for a processor and not have it compete for attention with other things on your desktop. I sell these works through the Sandra Gering Gallery, with which I've had a longtime association. I'm also using a computer-controlled laser to cut and engrave materials like acrylic. I am interested in how the lines and shapes from my algorithmic tools can be manifest in material form.[1]

[1]See <http://www.creative-capital.org> and <http://www.numeral.com/articles/atkins/decodingdigitalart>.

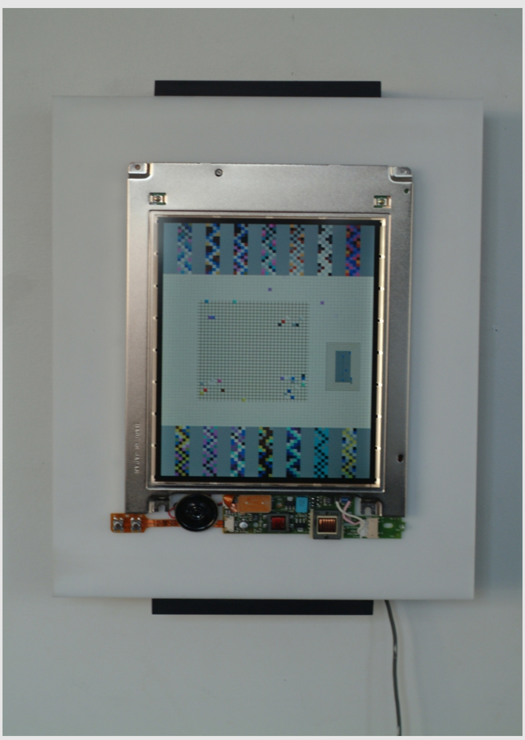

FIGURE 2.2.1 A work by John Simon. Photo courtesy of John Simon.

BOX 2.3
Terminal Time

Terminal Time is a mass-audience interactive work that constructs documentary histories in response to audience feedback. The result is similar in style to a Public Broadcasting Service documentary, except that the software constructs the documentary in real time, based on input from the audience. Thus, radically different endings are possible.

The work is produced in the following way. After a 2-minute introduction, the audience is asked three multiple-choice questions. The level of applause from the audience determines the "correct" answer to each question, with the loudest response winning. The answers to this first set of questions are used to create a model of the audience's ideological perspective, which is then used to create a 6-minute video clip representing history from 1000 to 1750 A.D. After the first clip is presented, the process is repeated two additional times, each resulting in the construction of another 6-minute clip, the first representing 1750–1950 and the second 1950–2000. The result is a film constructed in real time. One of the creators of Terminal Time likens it to a genie running amuck, in that the machine infers biases from the audience's responses and then constructs a reinterpretation of history based on exaggerating these biases.

The software running the Terminal Time engine uses an artificial intelligence (AI) architecture consisting of five parts: a knowledge base, a collection of ideology goal trees (goals held by different ideologues), a collection of rhetorical devices (narrative glue for connecting events), a natural language generator, and a media sequencer. Stored in the knowledge base are thousands of terms associated with historical events from the period 1000 to 2000 A.D. Based on an audience's response to each series of questions, the goal trees select historical events from the knowledge base and slant them to accomplish the rhetorical goals of the currently active ideologue. Next, the slanted events are connected together into a story by searching for a sequence of events that can be connected together with the rhetorical devices. The natural language generator then produces the text (based on the connected-together events) that will serve as the voiceover for the documentary. Finally, the system selects and edits together video and audio clips to create the finished documentary. To keep the audience engaged beyond the asking of questions, Terminal Time uses a thematic sequence of rising action, crisis, climax, falling action, and denouement for each complete film.

Cultural productions such as Terminal Time help to synthesize the metaphors of traditional AI, in which the emphasis is often on construction (e.g., to accomplish a particular goal), and art, in which the focus tends to be on conversation (e.g., to create a less-deterministic cultural product). Clearly, this type of cultural production would not be possible without information technology, and computer scientists could not generate this type of content without some knowledge from the arts and humanities concerning how to structure drama.

A second major challenge is the lack of a broad institutional support structure. After decades of experimentation and practice, new hybrid fields are emerging, but with lags in financial support.[18] Limited support, of course, results in limited growth for these particular fields. This is not necessarily bad, because the overall pattern of multiple hybridization results in a number of different intersections of the arts and design with computer science and engineering—different schools of ITCP thought and different kinds of activity—which together span the range from the fine arts through design and craft.

[18] See Chapter 6 for an extended discussion.

Multiple hybridization also militates against the institutionalizing of truly creative practice, as any institution formulated to support some particular conception of creative practice will necessarily curtail movement beyond that paradigm (and increasingly, as the institution becomes established).

Absent more funding for more experimental work, ITCP may become centered in a commercial, material core.

The growth in cross-disciplinary computing-in-the-arts curricula, which takes many forms, is likely to yield increasing numbers of multiskilled individuals capable of innovating in both technical and artistic/arts-related fields (although at least for a while, their impacts may be concentrated on the arts side, which appears to be more receptive to this type of cross-fertilization than does computer science). Funding may remain a chronic problem, however, for professionals who work (either alone or in groups) outside the commercial sphere.[19] The result is a certain amount of untapped creative energy or underemployment, which limits cultural production to a narrower bandwidth than otherwise might be possible with more generous funding. This situation constrains the breadth and spectrum of the technical syntax of ITCP: Absent more funding for more experimental work, ITCP may become centered in a commercial, material core. It may be more pronounced in craft and in design than in art, per se, or fundamental technical research.

SUCCESSFUL COLLABORATIONS

Collaborations in ITCP may differ from other kinds of collaborations in that they may well not be symmetrical. Given the differences in training, objectives, and culture, it may be important to articulate different goals between collaborators. A project can be successful and synergistic even if the differing participants have completely different goals for the fruits of the outcome of the collaboration. For example, a particular tool can be used in one way by a scientist and in another way by an artist—but they may develop the tool together (e.g., see the Listening Post project described below). Further, quite different types of relationships between the two communities are possible, each of which embodies different values and therefore requires different techniques in order to achieve success and devise methods for measuring that success.

Collaborations are intense, not superficial, relationships. Less intense forms of relationships include communication (the sharing of information) and cooperation (in which participants influence the decisions of other participants in a common effort). Collaborations may take place in various sizes and forms, ranging from a small project (e.g., academic researchers who agree to work together) to continuing activities within the framework of an institution created for such a purpose (e.g., the studio-laboratories discussed in Chapter 5), to large

[19]Because many artistic endeavors are driven by content—artists have their own vision and agenda—rather than profit, they often struggle for support.

commercial enterprises with well-defined and profit-motivated products. What they share is the intention of creating something larger than the sum of their parts. As once noted about the idea of artists working with engineers, "the one-to-one collaboration between two people from different fields always holds the possibility of producing something new and different that neither of them could have done alone."[20]

Non-commercial collaborations often cope with the same inadequate institutional support faced by multiskilled individuals. Such collaborations may often involve people early in their careers who are not yet highly invested in one field nor inhibited by professional norms. They have little to lose by pursuing work that the mainstream might consider marginal. In some cases, radical ideas are the point. The Critical Art Ensemble,[21] for example, is a loosely organized collective of five artists who use "tactical media" to explore the intersections of art, technology, radical politics, and critical theory. Starting out as students looking for a way of organizing that would provide enough financial, hardware, and labor resources to have a cultural impact, the collective now expands and contracts based on specific project needs; the members are geographically diverse and skilled across many disciplines. The results of the work take many shapes—Web sites, performances/installations, and books—which emerge through a horizontal, distributed think-tank process of discussion and exchange among participants. Projects are funded through the participants' "straight jobs," writing and speaking fees, and an occasional sponsor.[22]

Some non-commercial collaborative projects are both inspired and supported by institutions. An example is Bar Code Hotel, an interactive installation by artist/programmer Perry Hoberman that was among nine virtual reality projects produced by the Art and Virtual Environments project at the Banff Centre for the Arts.[23] In Bar Code Hotel (see Figure 2.2), "guests" enter a room in which the walls are covered with bar codes. The guests use a lightweight wand to activate the black lines in the symbols and issue directives such as "grow" or "fight" to virtual objects they create in a computer—semi-autonomous agents with their own personalities and behaviors. Thus, the guests create a narrative that is partly predetermined and partly spontaneous; when the objects "die" and the guests leave, the hotel returns to

[20]From Paul Miller, 1998, "The Engineer as Catalyst: Billy Klüver on Working with Artists," *IEEE Spectrum*, July, available online at <http://www.spectrum.ieee.org/select/0798/kluv.html>. Also see the work of Project Zero at the Graduate School of Education at Harvard University, available online at <http://www.pz.harvard.edu>.

[21]See <http://www.critical-art.net/>.

[22]See <http://www.lumpen.com/magazine/81/critical_art_ensembles.html>.

[23]See <http://www.perryhoberman.com>. Also see M.A. Moser and W.D. MacLeod, eds., 1996, *Immersed in Technology: Art and Virtual Environments*, MIT Press, Cambridge, Mass.

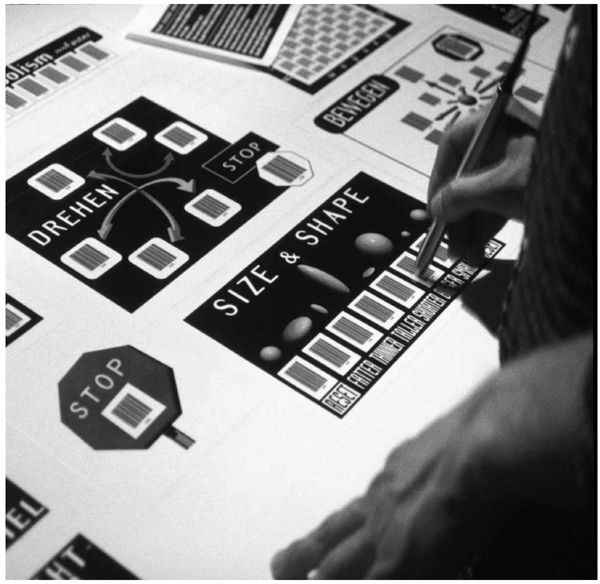

FIGURE 2.2 Bar Code Hotel enables guests to use commands embedded in bar code symbols to interact with semi-autonomous computer-generated objects and create a narrative. Photo courtesy of Perry Hoberman.

its original empty condition. Bar Code Hotel was produced through a hybrid work model in which the artist developed the concept but accomplished the work with help from others. The approach was similar to that of the film business (discussed below in this section) in that it was hierarchical: A producer (Banff) and a director (Hoberman) worked with a team of programmers, sound designers, animators, and other technologists and equipment provided at the Banff Centre.[24] Team members in such situations, while generally carrying out the director's concept, often provide essential ideas.

A small but institutionally driven collaboration, this time involving participants acting as equals, produced the highly successful Listening Post, which monitors online activity in thousands of Internet chat rooms and message boards and then converts these public conversations into a computer-generated opera. This project was instigated and supported by the Brooklyn Academy of Music (BAM), Lucent Technologies' now-defunct pilot program in new media, and by the Rockefeller Foundation. A symposium was set up at which artists and Bell Laboratories engineers and scientists each gave 5-minute presentations on their work and then had the opportunity to talk with each other and find compatible collaborators. Administration was handled by BAM, which awarded $40,000 to each of three

[24]For a comparison between Hoberman's directorial role in relation to programmers and other less partitioned team design in the Banff Centre's Art and Virtual Environment's project, see Michael Century and Thierry Bardini, 1999, "Towards a Transformative Set-up: A Case Study of the Art and Virtual Environments Program at the Banff Centre for the Arts," *Leonardo* 32 (4):257-259.

projects. Listening Post was created by two people—Mark Hansen of the Statistics and Data Mining Research Department at Bell Labs, whose cross-disciplinary research draws on numerical analysis, signal processing, and information theory, and Ben Rubin, an artist who works with interactive sound and image technologies. In Listening Post, bits of sampled text are presented as light-emitting diode readouts and variously pitched speech synthesized to form a screen of visual data accompanied by an "opera" of spoken text. Statistical analysis is used to organize the messages into topic clusters based on their content, tracking the ebb and flow of communication on the Web.

Listening Post demonstrates that collaborations not only draw on and assemble a wide variety of skills in newly developing areas of digital culture but also may alter creative practices themselves—the shape and nature of the way people work, and the way disciplines are defined and categorized. The boundaries of practice here were altered as a result of challenges that arose in the legal territories of intellectual property and licensing. Rubin also explained that, as a result of the collaboration, his "conceptual vocabulary has grown to include notions like clustering, smoothing, outliers, high-dimensional spaces, probability distributions, and other terms that are a routine part of Mark's day-to-day work." He added, "Having glimpsed the world through Mark's eyes, I now hear sounds I would never have thought to listen for." Hansen has expressed similar sentiments, saying: "This installation, its physical presence as well as the underlying intellectual questions, are new for me, as they are for Ben. I suppose it's the mark of a genuine collaboration, that the participants are led in directions they could never have imagined apart."[25]

Collaborations not only draw on and assemble a wide variety of skills in newly developing areas of digital culture but also may alter creative practices themselves.

At the other end of the spectrum of creative work models are larger groupings. Larger groupings tend to be structured according to either the directorial model (which is more common among first-generation media artists) or the low-ego model of distributed responsibility and anonymity (exemplified by the Institute for Applied Autonomy). Many groups have occupied some middle ground between these two. Longer-running collaborations such as Survival Research Laboratories have become a brand with a figurehead, a semi-permanent core, and a tiered and fluctuating membership. Larger, looser groupings occur over the Internet and have their own dynamics, all the way up to large virtual communities.

Some of the more structured and better-funded ITCP collaborations are those found in commercial endeavors, such as segments of the architecture, movie production, and computer game industries. In the film industry, for example, there is a clear hierarchy with well-defined jobs that form a pyramid of synergistic labor to carry out a standardized process of making a product with clearly defined parameters. Such collaborations depend on conventions of practice, standard technologies, and infrastructures for distribution. These are also

[25]See <http://www.earstudio.com>.

professional contexts in which collaborations are the norm, with built-in motivations and rewards for making the process succeed. A shared goal of generating some kind of product or service provides the extrinsic raison d'être for collaboration, communication, and coordination among disparate types of people. The following descriptions of work models in these fields may provide some guidelines for future collaborations of computer scientists and artists and designers.

Architecture

Architecture is inherently a collaborative field. Only the very smallest design and construction projects are conceived and executed by individuals. Projects of any scale and complexity are undertaken by large teams of specialists—typically including client representatives, architects, specialist engineering consultants, fabricators, subcontractors, and general contractors. The design architect plays a leadership and overall coordination role, taking ultimate responsibility for the quality of a project, but any member of a design and construction team may be called upon to help frame problems and to contribute to their solution. Experienced architectural designers know that innovative, creative projects depend on harnessing the expertise, energy, and imagination of all team members, not just assigning them routine tasks.

Forms of collaboration have evolved as supporting technologies have developed. Medieval architects, for example, were not clearly distinguished from builders, and they spent most of their time on construction sites rather than in separate design offices. Under these conditions, the interactions among team members mostly took the form of on-site, face-to-face discussions, augmented when necessary by the production of simple sketches and full-size templates of detail. With the industrial revolution, a more formalized division of labor emerged: Architects definitively separated from the construction trades, identified themselves as professionals, increasingly defined themselves as knowledge workers rather than as master craftsmen, and spent most of their time in their off-site ateliers and drawing offices. Drawings on paper became the principal means of developing and recording design ideas, communicating among members of the design and construction team, and establishing construction contracts. Within this new framework, drawings and scale models (rather than on-site construction situations) became the objects of discussion. Collaboration increasingly took place around the drawing board, or in a conference room.

Since the 1960s, digital technology has been transforming design and construction collaboration once again. Computer-aided design (CAD) files have replaced drawings on paper as the primary records of evolving designs. Electronic file transfer and joint access to online databases have increasingly supplanted the physical transportation of drawings as means of communication among design team members.

Videoconferencing and groupware (software tools to support collaboration) play growing roles. As a result, design and construction teams may now be tied together electronically rather than by physical proximity in their interactions and collaborations, they may be distributed geographically, and they may operate asynchronously across multiple time zones.[26] Whereas architecture was once a very local activity, it is now globalizing.[27] Globalization, in this context, means that design and construction teams are not limited to the talent and expertise available locally. They can draw on much larger, more diverse, and competitive talent pools. It is not necessary to go to the structural engineer next door, for example; one can go to a leading international specialist who has exactly the right skills and experience for the current project.

The shift to digital modeling and fabrication based on computer-aided design and manufacturing (CAD/CAM) also provides significantly greater design freedom. Architects can now work, without difficulty, with complex curved surfaces, non-repeating compositions, and other elements that would have been completely unmanageable in the days of hand drafting. And they can use sophisticated software, applied to digital models of projects, to verify structural, thermal, and other aspects of performance. Projects that would have been imaginable but infeasible in the past can now be pursued without much difficulty (see Figure 2.3).[28]

Architects can now work with complex curved surfaces, non-repeating compositions, and other elements that would have been completely unmanageable in the days of hand drafting.

Movie Production

The movie industry exemplifies cooperative creative practices, relying on collaborative processes involving artists and technicians to make its magic. Temporary task forces of actors, designers, electricians, animators, and many others come together for a single project, working intensely to build relationships and teamwork comparable to that of a string quartet or baseball team.[29] The director may work with writers or composers to develop and revise the screenplay or score, designers and technicians may work together to make the sets, and film editors may rely on digital technologies to create special effects. A

[26]Similar processes have, of course, unfolded in manufacturing and other contexts where artistic concerns may be less evident (other than in the design component as discussed above).

[27]See Jerzy Wojtowicz, ed., 1995, *Virtual Design Studio*, Hong Kong University Press, Hong Kong; and Jose Pinto Duarte, Joao Bento, and William J. Mitchell, 1999, *The Lisbon Charrette: Remote Collaborative Design*, ISP Press, Lisbon.

[28]See, for example, William J. Mitchell, 1999, "A Tale of Two Cities: Sydney, Bilbao, and the Digital Revolution in Architecture," *Science* 285 (August 6): 839-841; or William J. Mitchell, 2001, "Roll Over Euclid: How Frank Gehry Designs and Builds," pp. 352-364 in *Frank Gehry, Architect*, J. Fiona Fagheb, ed., Abrams, New York.

[29]See Computer Science and Telecommunications Board, National Research Council, 1995, *Keeping the U.S. Computer and Communications Industry Competitive: Convergence of Computing, Communications, and Entertainment*, National Academy Press, Washington, D.C., p. 33.

FIGURE 2.3 Guggenheim Bilbao. Photo courtesy of William J. Mitchell, Massachusetts Institute of Technology.

Hollywood production literally demands this vast array of talent and skill (witness the length and diversity of the credits on a typical film). Then, when the project ends, the team dissolves and the individuals seek new employment elsewhere.[30] Movie production can also exist on a smaller scale—from the experimental to small-budget independent films. These smaller-scale efforts are also collaborative in nature, with profit or revenue as a less important consideration than it is for mega-Hollywood-scale projects.

Movie production has embraced IT. Indeed, over the past two decades, virtually every facet of movie making has been transformed by IT. Computer-generated imagery (CGI) is commonplace, from the dinosaurs in *Jurassic Park* to the "legless" lieutenant in *Forrest Gump*

[30]For economic analysis of the evolution of the formerly dominant studio system to one based as described here, see Richard E. Caves, 2000, *Creative Industries: Contracts Between Art and Commerce*, Harvard University Press, Cambridge, Mass.

and Gollum in *The Lord of the Rings: The Two Towers*. *Jurassic Park* made history by showcasing the ability to successfully model, render, animate, and composite three-dimensional images at film resolution.[31] Since that film was made, CGI has advanced to the point that, in the words of *Titanic* director James Cameron, "Anything is possible right now, if you throw enough money at it, or enough time."[32] Digital technologies also extend to sound recording, sound production, and picture editing.

The smaller studio and independent film markets also have been transformed by the advent of digital video. The increased scale and portability of cameras have changed shooting styles and are beginning to evolve new aesthetic possibilities. Lower costs are expanding access and the possibilities for experimentation. Thus, niche markets are developing for lower-budget films and are causing an explosion of low-budget production. Desktop tools for postproduction in editing sound as well as animation and special effects are also creating access for a whole new generation of filmmakers. Ironically, as this lower-budget end of film making has achieved commercial viability, it also has tended to compete with the experimental and non-commercial arena of film making for resources, such as access to venues.

Desktop tools for postproduction in editing sound as well as animation and special effects are creating access for a whole new generation of filmmakers.

Animated work is now being digitized on the scale of feature-length films, as evidenced by the release of *Toy Story* in the mid-1990s. What had been confined to special effects or short demonstrations since the late 1970s has reached a level of maturity able to convince audiences at the subtlest level of expression—character animation, long believed to be beyond the capacity of computer animators. A new Oscar category has been created for "best animated picture"—and the honorees are just as likely (maybe more likely) to be digital artists as traditional cartoonists who draw characters by hand. In fact, many cartoonists are losing their jobs; membership in the screen cartoonists union has dropped by almost 50 percent in the past 5 years.[33] Of course, computer-system animators and cartoonists alike have seen a considerable volume of their work become industrialized, given the division of labor associated with producing a contemporary theatrical film. This does not necessarily spell the end of individual artistry, however, although there is the risk that such artistry is migrating to other realms. Some predict a resilient market for the warmth of traditional animated characters; there may also be new avenues for individual creative practice as the costs of digital workstations fall.[34] Experimentation with short works designed for Web distribution provides

[31]Scott McQuire, 1999, "Digital Dialectics: The Paradox of Cinema in a Studio Without Walls," *Historical Journal of Film, Radio and Television*, August, available online at <http://www.findarticles.com/cf_0/m2584/3_19/55610007/p1/article.jhtml?term=+>.

[32]Cited in McQuire, 1999, "Digital Dialectics."

[33]See Claudia Eller and Richard Verrier, 2002, "Animation Gets Oscar Nod as Industry Redefines Itself," *Orlando Sentinel*, February 12.

[34]See Eller and Verrier, 2002, "Animation Gets Oscar Nod."

an outlet for creativity in animation, while the definition of "animation" itself is evolving: Time re-mapping and digital compositing on existing footage extend the notion of animation into territories within film, and in some ways, computer-generated imagery has made all of film into a form of animation.

Computer Games

Today's game industry, which produces interactive media for personal computers, game consoles (i.e., Playstation 2, Xbox, and Nintendo Game Cube), and online games, is an increasingly important force in youth culture and the economy—video games make more money than the Hollywood box office.[35] Even more than film, computer games require a close marriage between the practical aspects of code and art, and between programmers and artists, at every stage of production. It is not just that different skills are required to produce the end result. Rather, it is the constant state of communication among art, technology, and design that has to be maintained from beginning to end, in order to ship a product.

There are three groups of people involved in the production of a game: designers, programmers, and artists. Designers are responsible for the structure of the experience and the dynamics of interaction between players, or between players and the game world. Programmers are responsible not only for the code that makes this interaction possible, but also for the tools that are used to build the world—unlike film or architecture, most games are built with custom tools because the technology changes so fast. Artists are responsible for the surface of the game—the topography and texture of the world, the way characters look, the animation that occurs when the player takes any kind of action. In the course of production, from concept to completion, these three groups have to work to achieve an almost spousal level of understanding, because their jobs are so interdependent. Designers have to work with programmers to shape the toolkit, to ensure that player interactions will be technically possible. Artists have to talk to programmers, so that they will have enough polygons (or digital objects) to do what they want as well as suitable textural and procedural complexity and character development. Designers and artists must collaborate closely because look and feel are inextricably intertwined. All three groups contribute to the development of game "engines,"[36] which can be reused to develop different games. Game en-

[35]According to a report by the NPD Group (as reported in Khanh T.L. Tran, 2002, "U.S. Videogame Industry Posts Record Sales," *Wall Street Journal*, February 7, p. B5), sales of video game software were $9.4 billion in the year 2001, while U.S. box-office receipts totaled an estimated $8.35 billion. Also see Khanh T.L. Tran, 2002, "Consoles Outrun Computers," *Wall Street Journal*, April 19, p. A13.

[36]A game engine supports the basic software elements needed to develop a game, which include rendering, support for sound handling, and other elements and can be reused for other games.

gines have become sufficiently sophisticated that their development is emerging as a category of problems addressed in computer science research.[37]

If the game is played online, all of these groups have to work with a fourth technical group, which oversees the network platform that supports online interaction; this group is responsible for the databases, server arrays, network security, bandwidth allocation, and so forth. Although multiplayer online games may be constrained by network architecture and capabilities, they also may inspire new research and development in these areas. Even something as simple as a player looking through a doorway requires multiple forms of expertise: Can the player see other people outside? If so, that information has to be streamed onto the player's computer—and if there is a crowd outside, performance may suffer. Perhaps there is a way to limit the field of vision (a conversation between programming and design) or compress the graphics files (compromises among art, design, and engineering). Can the other people see the player? (This involves the same issues and more database work.) Instead of segregating tasks, development teams conventionally tackle cross-disciplinary problems by assigning "strike teams," composed of an artist, a programmer, and a designer, to specific problems: artificial intelligence, in-game resources, and so on. High-level, cross-disciplinary collaboration is a daily fact of life. See Figure 2.4.

This level of collaboration exists in part because game technology is a moving target. The medium is evolving so rapidly that many games solve problems that did not even exist a year before, because the tools were not there to solve them. The creation of custom tools to take advantage of leading-edge capabilities means that such teams are working on the edge of what is technically possible, to make a great experience for the player (unlike film, which leverages standardized technologies to a larger degree). Game companies do not have research and development (R&D) departments because every product is a collection of (applied) R&D that eventually has to work, one way or another. In the words of one lead designer, "Every game is a moon shot."[38]

A concept from this industry that may be applicable to other ITCP activities is the leveraging of user talent (not unlike the audience participation in Terminal Time and Bar Code Hotel). The computer game industry is an example of cultural production as a technology

[37]Game-engine development has been the focus of doctoral dissertation work at the Naval Postgraduate School's MOVES Institute, for example (personal communication, Michael Zyda, Naval Postgraduate School, March 2002).

[38]Of course, it is worth noting that not every game pushes the technology envelope. Some games, for example, exploit new ideas about social and storytelling approaches that may or may not involve challenging technological problems to solve. And other games may be mostly derivative in nature, using only well-established technology and techniques.

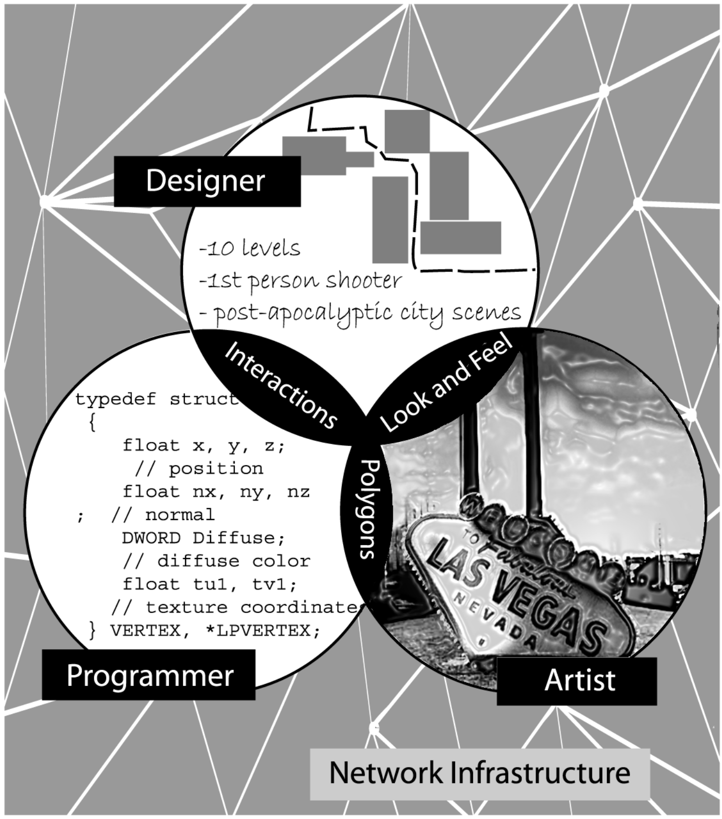

FIGURE 2.4 Development teams for computer games. Illustration created by Jennifer M. Bishop, Computer Science and Telecommunications Board staff.

and market driver, where software engines and authoring tools are regularly made available to end-consumers who use them to redesign or extend the core product, often in directions unanticipated by the publisher. Even something as seemingly reductive as Quake, a first-person shooter, has been reconfigured as a low-tech animation engine—players use the game's editing tools to build environments and characters, which are then manipulated as virtual actors. This is not a market the publisher would have envisioned, much less approached. On the technical side as well, player innovations have driven the artificial intelligence component of the game forward, resulting in smarter code that drives not only sales of the end-product but also commercial licensing of the underlying technology to third-party publishers. Essentially, the flexibility of Quake's tool set has transformed thousands of players into a self-organizing market research and R&D force driven by its own creative imperatives and social incentives.

CULTURAL CHALLENGES IN CROSS-DISCIPLINARY COLLABORATIONS

Would-be collaborators from different disciplines can encounter a number of obstacles, including difficulties in accessing appropriate funding sources, differences in vocabulary, the absence of frameworks for evaluating non-traditional work, and the long time periods required for projects to gel.[39] Further, it may seem intuitive that the greater the differences between the disciplines involved, the higher these barriers become; one could argue that IT and the creative arts register a high score on this scale. Yet, some claim it is easier to get artists and engineers to work together as a team than it is to get individuals from either group to work with their own colleagues in the same field. That observation has been applied to both computer science and various arts and design fields. Sometimes competition in the same (or a similar) area of expertise is more difficult to deal with than combining different skill sets to attain a common goal.

When adequate resources are available, as is sometimes the case in the corporate world, people can be formally taught skills that are conducive to collaboration. The committee made a site visit to Pixar Animation Studios,[40] a successful company that offers a number of creativity-enhancing activities. Corporate universities, per se, are not new; for example, the Disney Studio offered art classes in its heydey of the 1930s and 1940s.[41] But there is something unusual about Pixar University, a part of the company that has its own "dean" and offers courses in every aspect of filmmaking for Pixar employees (the classes include both technical and artistic "students"). The curriculum includes many forms of studio art (e.g., sculpture, painting, drawing), improvisation, storytelling, and even juggling. Pixar co-founder and president Ed Catmull says a course in improvisation is the closest thing there is to a class in how to collaborate. Perhaps the strongest statement that can be made about these offerings is that they send a signal, coupled with enabling resources and management support, that creativity matters, is encouraged, and may be rewarded, and that it can involve moving beyond one's starting skill set, whether on an individual basis or in combining people with different starting skill sets into teams. In addition, Pixar University contributes to the company's human resources policy by promoting employee retention. Unlike other major studios, Pixar tends to keep its teams together

[39]See National Research Council, 2000, *Strengthening the Linkages Between the Sciences and the Mathematical Sciences*, National Academy Press, Washington, D.C.

[40]See Appendix B for a listing of Pixar participants.

[41]See Frank Thomas and Ollie Johnston, 1981, *The Illusion of Life: Disney Animation*, Abbeville Press, New York.

between projects, rather than laying them off. There are downsides, of course, to any strong internal culture, even one designed to promote collaboration and creativity. A self-contained organization without links to external perspectives may encourage homogenous values and an insular view of the world, discouraging the criticism or controversy that often is useful in ITCP work.[42]

Even if specialized training is not an option, general awareness of key issues that arise in collaborations may help projects to succeed. The overall challenge in collaboration is to transcend traditional role boundaries to exploit different perspectives and skills and create new ideas and products that are somehow greater than the sum of their parts. Doing so may involve assessing the multiple dimensions of each relevant discipline—which affects its interfaces to others—and the ongoing processes of change affecting each discipline. Specific obstacles to be overcome at the intersection of IT and creative practices are discussed in the following subsections.

Overcoming Preconceived Notions About Computer Scientists and Artists and Designers

Perceptions about artists and designers and computer scientists can often be formed through popular or anecdotal accounts, rather than through actual encounters. Such perceptions can inhibit mutual respect in collaborations, at least at the outset. The challenge of overcoming such stereotypes permeated the personal accounts of those who briefed the committee and of committee members themselves.[43] Although there are exceptions to and disagreements about stereotypes, some generalizations are useful here for bringing an important issue to light, even at the risk of oversimplification.

Some scientists and engineers exhibit a sense of superiority, if not outright hostility, toward those in the arts and design. Or, put another way, "Artists see science; they don't understand it; they think it is brilliant. Scientists see art; they don't understand it; they think it is dumb."[44] Part of the problem may be the connotations of "creativity" in some contexts. Creativity is often cloaked in an aura of mystery, which suggests that the work results from spontaneous creative insight without rigorous or repeatable methodology, from epiphanies

[42]However, companies that wish to keep their work confidential until public release do have reasons for constraining external communication, or at the least, not encouraging it fully.

[43]Of course, such perceptions do not exist in every collaboration. However, testimony to the committee, a review of published literature, and the experiences of most of the committee suggest that the lack of such perceptions is indeed the exception.

[44]Based on discussions at the committee's meeting at Stanford University, January 2001. A reviewer of this report observed that "sentiments here attributed to scientists are seldom encountered among European scientists, probably because U.S. scientists are often unfamiliar with cultural practices."

when alone rather than as a result of sustained discussion with peers; it downplays the analysis, struggle, debate, or committed engagement with pressing social or technical problems. It is very difficult to compare forms of creativity, or sometimes even to recognize them. Some scientists and engineers can also view the arts or other cultural perspectives as luxuries, things that might be supported or pursued as time and resources permit.

Such attitudes may be traceable in part to disparities in funding and, accordingly, some notion of status.[45] The Xerox Palo Alto Research Center (PARC) Artist-in-Residence (PAIR) program, for example, received a certain amount of attention for its attempts to integrate artists with computer scientists and others.[46] Although this program may well have helped Xerox PARC to sustain its creativity, constraints on social integration—accentuated by pay differences—may have limited the creative output.[47] Although people can (and, given discussions within the committee, clearly do) interpret compensation disparities in different ways, national employment statistics show significant differences among workers in the arts and those in technical fields such as computer science; different occupations, even among technical fields, have different earning power, for a variety of reasons that derive from the structure of the economy (and professional conduct).[48] The marked contrast between compensation levels for computer scientists and for artists, other things being equal, is significant for the intersection between IT and the arts inasmuch as it affects collaboration and education. Across organizations, and even departments in a university, compensation levels affect patterns of time use, expectations for research and for infrastructure, and so on.

Similarly, the arts establishment sometimes regards technology suspiciously, as if it lacks a worthy lineage or is too practical to be creative. This attitude was evident in early committee discussions, coming out most strongly in contrasting perspectives on the potential for creative practices within industry. Because of their experience in

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[45]As Michael Mateas, creator of Terminal Time, told the committee: "Power is a big issue . . . . Certainly in our society there's a power asymmetry between technocrats—scientists and technologists—and artists. Technocrats are . . . in the driver's seat right now in our society."

[46]The context is a research laboratory that had already blended a variety of scientists and engineers and a small group of social scientists.

[47]As characterized to the committee at its January 2001 meeting at Stanford University, the PAIR program when it was launched included "creative" people from the arts with a lot of experience who were paid less than some technical student interns, and who disparaged the scientists as suburban bourgeoisie.

[48]According to economist Richard Caves, creative professionals earn less, on average, than their human capital might suggest, in part because their commitment to producing creative output may lead to different activity and output than would a simpler commitment to satisfying consumers. See Richard E. Caves, 2000, *Creative Industries: Contracts Between Art and Commerce*, Harvard University Press, Cambridge, Mass.; and James Heilbrun and Charles M. Gray, 2001, *The Economics of Art and Culture*, Cambridge University Press, Cambridge, U.K.

deriving research inspiration from practical problems, the technologists found it easier to see creative potential in industry than did the artists, who found more cause for concern about motivations or constraints based on commercial imperatives.[49] Skepticism about technology was also evident in the early days of "Net art" (art using the Internet), which took off in 1994 when the Mosaic browser was first distributed and people realized that the Web was a fertile canvas for art making. Net art was ignored as unimportant at first by art institutions, museums, galleries, art magazines, and funders. (Now that it has gained credibility, some suggest that Internet art may in fact be the medium that best reflects the transformations of the information revolution, the same role that photography and film played in the industrial revolution.[50]) This type of cultural bias can undermine respect and communication, unless the participants are aware of their differences and are willing to modify their behavior appropriately. Although the committee context forced the process of articulating and overcoming such differences among its members, accommodation was neither rapid nor easy, an insight that is important for planning for other contexts.

Cultural bias can undermine respect and communication; overcoming such differences was neither rapid nor easy, an insight that is important for planning for other contexts.

One concern arising from some quarters of the arts world is that a celebration of the potential of ITCP not become a dirge for more traditional forms of art.[51] One is not a substitute for the other; both should be viewed as complements. Nor should ITCP be viewed as privileging popular forms, such as design, over the fine arts. Although the direct pop culture, because it is so pervasive and so easy to learn and transmit through media, has pushed developed art to the margins, both ends of the spectrum need each other—the direct end to revitalize points of view and connect with basic feelings, the other to reveal much more about an idea (and about ideas) than was first supposed.

The challenge of maintaining respect across disparate fields is an extension of the frequent differences in attitude encountered within a field between researchers in the more theoretical and the more applied areas. More generally, every social context has a prestige and status hierarchy, standards of excellence, standards of language, and modes of expression. It is too late to establish social contexts for ITCP de novo so that everyone is socialized ab initio into shared norms, goals, and expectations. Hence it is important to foster social contexts that recognize explicitly that people come from different cultures and explicitly work to bridge those differences. Establishing strong common goals and simultaneously ensuring individual work satisfaction—the support of individual goals within the group—is one strategy for cross-

[49]This perspective is likely to be more common among studio artists than, for example, commercial artists who work in advertising or industrial designers.

[50]Based on a presentation by Mark Tribe to the committee in November 2000 in New York City.

[51]This theme emerged in the review process for this report, for example.

disciplinary communication. Creating an atmosphere of equal value among members is another tactic. Dissension flourishes in an atmosphere of inequity; the collaborative process requires an atmosphere that allows for relaxed exchange.

Perceptions of teamwork in the arts have, in the past, centered on either identical roles (i.e., people working together as equals) or clearly unequal ones (e.g., one person is "in control" and the other is the technician or helper). These models are changing in the wake of new practices such as those used by the Critical Art Ensemble, discussed above. Differentiations between "technicians" and "professionals" shape computer scientists' views of collaborations, too, especially in a cross-disciplinary context. Because people play different roles in teams, assigning credit can be difficult. A major impediment to cross-disciplinary collaborations is the traditional academic focus on isolated disciplines, the organizing principle for departments, journals, and the reward system for teachers and researchers.[52] New technological art forms require new ways of organizing, which can take decades to stabilize, as was true for cinema and perhaps for emergent forms such as virtual environments.[53]

New technological art forms require new ways of organizing, which can take decades to stabilize, as was true for cinema and perhaps for emergent forms such as virtual environments.

MINIMIZING COMMUNICATIONS CLASHES

Although the arts and sciences are not completely separate spheres—indeed, some see them as intricately related—they do speak different languages. During the writing of the present report, for example, committee members and staff with IT backgrounds had difficulty understanding the nonlinear concepts and writing style of those with art and critical studies backgrounds. Similarly, a Stanford University computer science professor reported difficulty in collaborating with art historians because they were unfamiliar with data and models.[54] Simply recognizing the barriers posed by jargon, terms of art, and localized practices goes a long way toward bridging such gaps. The Textile Museum in Washington, D.C., for example, took a straightforward approach in demystifying its exhibition of textile art made with digital printing and/or digital weaving techniques, which "allow the artists to investigate traditional textile concepts with a new flexibility and range of creativity."[55] Because casual visitors might have had difficulty understanding either the art pieces or the advantages offered by technology, the museum provided a glossary of textile terms such as "warp" and "weft."[56]

52 See Chapter 6 for a detailed discussion.

53 See Brenda Laurel, Rachel Strickland, and Rob Tow, 1994, "Placeholder: Landscape and Narrative in a Virtual Environment," *ACM Computer Graphics Quarterly* 28(2):118-127.

54 Personal communication from Marc Levoy, Stanford University, March 29, 2000.

55 See "Technology as Catalyst: Textile Artists on the Cutting Edge," 2002, Textile Museum, Washington, D.C.

56 See "An Introduction to Textile Terms," 1997, Textile Museum, Washington, D.C.

Communication—not only the words but also the style—is an important issue for collaborators. Education and training shape expectations for communication; they can also factor into receptivity to the vocabulary and styles of others. In a productive architectural process, roles are flexible and the many actors can cross professional boundaries and interact in ways that enable creative things to happen. If an architect knows something about structural engineering, and a structural engineer knows something about architecture, they can perform their specialized roles at a sophisticated level of discourse. For instance, the architect can tell the engineer that a column is oversized and know, without being told, that it could be cut in half. They know enough about each other's jobs to communicate across role boundaries. Thus, mechanisms such as crossover books (books that are intended for non-specialist audiences) can be useful; such books boil down the essence of an area for the intelligent and interested novice. However, these adaptations must not be so diluted that real insights are obscured by superficialities.

It is no secret that scientists and artists have widely differing community standards with regard to language and modes of expression and the types of questions to explore. As noted by Michael Mateas, for example, the scientist seeks abstract and objective knowledge, whereas the artist seeks an immediate perceptual experience for the audience.[57] Accordingly, it can be difficult for them to reach consensus on common problems and topics and to establish common understandings.[58] Yet there are also rapid changes redefining practice that are blurring previously rigid boundaries, as collaborators find ways to accommodate their differences. As noted by a reviewer of this report, successful collaborations involve mutual respect and friendship: Each knows enough about the other's field for meaningful conversation to take place, but respects the other's expertise enough to leave specialized decisions to that collaborator. Shared goals, group dynamics, and psychological maturity are more important than complete coverage of required expertise.

[57]Although scientists and artists may have different motivations, and public appreciation may play a relatively greater role in artists' visibility and income, in both cases professional advancement depends heavily on the judgment of peers.

[58]See Denise Caruso, 2001, "Lead, Follow, Get Out of the Way: Sidestepping the Barriers to Effective Practice of Interdisciplinarity," white paper, Hybrid Vigor, see <http://www.hybridvigor.org>.

RESOURCES THAT SUPPORT CREATIVE PRACTICES

SKILLS TRAINING

Work in ITCP not only demands new capabilities from many of its practitioners, but also offers novel avenues for learning these skills. That is to say, IT can be exploited both to help technologists and artists learn skills and methods and gain access to tools, and to motivate and educate others, including young people, who might one day become active in the field. This last point is important, because children naturally possess both the experimentalism and the fascination with computers that drive success in this field. Online vehicles are already supporting distance education, including instruction in new methodologies in general and the use of specific tools. Organizations that produce tools are increasingly turning to the Web as the medium of choice for providing educational material, supporting user-directed learning.

There seem to be more resources offering IT skills training and tools than offering arts education, paralleling what some see as an asymmetry in the motivation of artists and technologists to "cross over" into the other domain. There is a belief that, in general, artists can learn IT faster than technologists can learn art, in part because artists are more motivated to use IT as a way to do exciting and distinguished work (e.g., in computer animation). Technologists generally have little general education in art and tend to see the beauty of finding and solving problems in programming and mathematics as their art; in addition, they are paid well in their chosen profession and have less motivation to learn art or design.[59]

An important resource in the mid- to late-1990s was Open Studio: The Arts Online,[60] a national initiative of the Benton Foundation and the National Endowment for the Arts that provided Internet access and training to artists and non-profit arts organizations. According to promotional materials, Open Studio empowered the arts community to "give the Internet a soul," helping artists and arts organizations gain powerful new opportunities to network, strengthen ties to communities, and build new audiences, while ensuring that the online world is a source of creative excellence and diversity.

Technology plays a role in education at Eyebeam Atelier, where the goal is to expose broad and diverse audiences to new technologies and the media arts while simultaneously establishing and articulating

[59]Based on a personal communication from Bill Alschuler, School of Critical Studies, California Institute of the Arts, 2002.

[60]See <http://www.openstudio.org>.

new media as a significant medium of artistic expression.[61] Eyebeam accomplishes this objective through three core outlets: education, exhibition, and an artist-in-residence program. The education programs focus on exposing youths, families, and the general public to new-media art using the atelier method, in which an emphasis is placed on studio-based education augmented by technology, and through one-on-one instruction and mentoring. The new artist-in-residence program connects artists with "technology partners," primarily for-profit firms, that provide the technology needed by the artist. The partners share a common goal of exploring the technology's potential in the process of making art.[62]

Relevant online resources are not focused exclusively on the technology side of the ITCP equation. Practitioners can learn elements of artistry as well. For example, mH2O provides the software and samples (short loops of beats, instruments, and vocals) for anyone to create and record music. It also offers a variety of resources including digitized classes with master musicians. For example, users can select from five lessons (on topics such as the "Doodle System" and the "Ooo Bah System") with Clark Terry, a master of the trumpet and flugelhorn, who teaches form, phrasing, articulation, riffing, and other elements of the blues to a group of students at a high school in Connecticut, a project organized by the Greater Hartford Academy of the Arts.

Advances in IT can enable new modes of learning. For example, Maestro Pinchas Zukerman held a videoconference chamber music demonstration and discussion using Internet2 networks and peer networks, CANARIE, and NYSERNet. Zukerman led the class from Ottawa to a talented young string trio in New York. Audience members at Columbia University as well as observers on the Internet could watch the session in real time. A question-and-answer session was held for both in-person and Internet observers.[63]

WORK SPACES

Appropriate work spaces are an essential ingredient in creative production.[64] People need a comfortable setting offering access to their tools and collaborators. Most discussions of IT work spaces assume the conventional form factor of computing: a screen, a keyboard, and a mouse. Add in all of the normal peripherals of scanner,

[61] See <http://www.eyebeam.org/about/profile.html>.

[62] See <http://www.eyebeam.org/artists/index.html>.

[63] See <http://www.columbia.edu/acis/networks/advanced/zukermaninteractive>. Also see *Cultivating Communities: Dance in the Digital Age,* Internet 2, University of Southern California, October 29, 2002, <http://apps.internet2.edu>.

[64] "It is easier to enhance creativity by changing conditions in the environment than by trying to make people think more creatively." See Mihaly Csikszentmihalyi, 1996, *Creativity: Flow and the Psychology of Discovery and Invention*, Harper Collins, New York, p. 1.

printer, telephone, and so on, and the space suddenly needs a desk and a chair. Then information has to be stored in folders, files, drawers, and shelves. Suddenly the work space is an office. Is the artist/designer studio of the future really a conventional office?

Contemporary work spaces are in flux. During this time of change (or evolution), ITCP practitioners might be best served by flexible and open designs that allow for new configurations to alter the flow of work and communication. Wired spaces (in which there are distributed communication systems for Internet or broadband access) and wireless spaces (areas set up for pervasive access to wireless communications for access to the Internet and to people or devices within the area) are a new part of this landscape. The re-thinking of design for knowledge sharing, through both physical proximity and electronic communication, is an important part of creating new work processes and has to evolve hand in hand with space planning. How can these processes be facilitated in ways that allow for the flexibility and cross-pollination that are desirable in facilities for research and creative production? How can environmental adaptability, and signaling that colleagues are available, be achieved without the suggestion of a surveillance culture? Does electronic networking really reduce "one person–one computer" isolation? How is it possible to create spatial configurations that reduce isolation and foster or enhance discussion?

In the future, devices will get tinier and interfaces will become more complex. The world will have more buttons to push, more gadgets to carry, and/or more systems embedded in the environment (physical or natural) that provide services without direct human interaction. Or perhaps there will be systems for direct input to or output from human brains, possibly through implanted devices. Simply imagining something with visual or physical form could spark an entire sequence of events to occur in the physical world. The boundaries of the real and the imaginary could become obscured. There might be no need for a physical workplace, at least for utilitarian reasons—although there may be essential social needs that are unfulfilled in a virtual workplace. One might just imagine a workplace, and it would appear just as imagined. Early indicators of such phenomena can be found in experiments with virtual worlds, although virtual- and augmented-reality technologies engage a broader range of senses for inputs and outputs than those accessible to ordinary office or home computing systems.[65]

The desktop will most likely have to change to enable a more sophisticated dialogue with digital media. A variety of technologies offering three-dimensional graphics, voice and touch input and output, rapid macro-fabrication capabilities, and terabytes of storage all point to a potential diversification of tasks involving IT and an in-

[65]See Computer Science and Telecommunications Board, National Research Council, 1997, *More Than Screen Deep: Toward Every-Citizen Interfaces to the Nation's Information Infrastructure*, National Academy Press, Washington, D.C.

crease in activities that seem to be more versatile and challenging. In the end, environments have to be engaging on many levels for users to have the necessary impetus to respond with impassioned content—to be creative.

Virtual spaces can be architectures for collaborations that allow multiple users to talk and share work and work space across geographical territories. These capabilities are changing the nature of collaborative work as well as the markets and audiences for it. The ability to access and work with a niche group that is broadly distributed geographically allows for new kinds of practice to evolve. Skills that were previously determined locally no longer need be, and audiences that once had to be concentrated at a local level to make the activity economically viable can now be spread over a wide geographical area. These practices and methods of communication are beginning to generate new tools and work methods as well as new territories of content. Academic institutions and research facilities can become leaders in this area, empowering people to experiment in a non-prescriptive way.

As one example, the entire economy of music production has been transformed by digital technologies. Large commercial studios and studio musicians are vanishing as the home studio becomes the standard for production in both the commercial and non-commercial spheres. These studios can now access a level of technology previously unavailable to the individual and will certainly produce new forms of sound design. But technology and social infrastructures have to be developed carefully to avoid jeopardizing social interactions, in which people learn how to play with each other in groups. Access to tools and to other musicians through electronic networks has tremendous potential. It is possible to think of situations, in academic and research institutions as well as in commercial and non-profit production facilities, in which musicians and composers can collaborate both physically and electronically, or virtually, with enhanced potential for discussion and research. A convention of distributed performance has developed—a concert with some players at one site and some at another, or people waving across videoconferencing systems. But the increasing diffusion of broadband technologies[66] has begun to suggest a more complex and sophisticated set of possibilities for multisite performance, including collaborative production and development and new methods of distribution.

[66]See Computer Science and Telecommunications Board, National Research Council, 2002, *Broadband: Bringing Home the Bits*, National Academy Press, Washington, D.C.