Design in the Age of Information: A Report to the National Science Foundation (NSF)

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Abstract
The Information Age is upon us - it has become a global force in our everyday lives.

But the promise of significant benefits from this revolution, which has been driven largely by technologists, will not be realized without more careful planning and design of information systems that can be integral to the simultaneously emerging user-cultures. In cultural terms, information systems must be effective, reliable, affordable, intuitively meaningful, and available anytime and everywhere. In this phase of the information revolution, design will be essential.

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Design in the Age of Information

A Report to the National Science Foundation (NSF) By:

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Raleigh, North Carolina
July 31, 1997

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Any opinions, findings, and conclusions or recommendations expressed in this report do not represent a consensus of the steering committee, nor do they necessarily reflect the views of the National Science Foundation or North Carolina State University.

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# Design in the Age of Information

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0.0 Acknowledgements

This report is an effort by the steering committee, editors, advisors and participants, to discuss the role and responsibility of designers in the Information Age, and to stimulate new ideas, dialogue and research.

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0.1 Executive Summary

The Information Age is upon us — it has become a global force in our everyday lives.

But the promise of significant benefits from this revolution, which has been driven largely by technologists, will not be realized without more careful planning and design of information systems that can be integral to the simultaneously emerging user-cultures. In cultural terms, information systems must be effective, reliable, affordable, intuitively meaningful, and available anytime and everywhere. In this phase of the information revolution, design will be essential.

This report is the result of a 1996 workshop held in Raleigh, North Carolina and offers some answers to questions posed by NSF:

1. What can designers do expertly and what would be their unique contribution to these developments?
2. What are the principles that govern design in the future of an information society?
3. What kind of research would be needed to make design a partner in the emerging information society?
4. How can we help design to make the contributions it can, whether by financing programs for developing new approaches to design, supporting new educational initiatives, or underwriting research projects that are likely to move the national information agenda ahead?

In the introduction to this report, in 1, we identify four “transformations” that form the ground on which the role of design in an age of information can be understood:

- **Digitalization** enables us to compose artifacts with extremely small and numerous units and to compute at staggering speeds.
- **Networking** enables us to link these units across time and space and bring people that would otherwise never know of each other together with heretofore unimaginable resources.
- **Equity of access** is not just a prerequisite of the new technology, which is more beneficial to each user the more people participate. It might just be the criterion by which we could realize our democratic ideals in ways the industrial age could not. These technological possibilities are redefining
citizenship, creating new institutions, and transforming work.

- Information technologies require considerable creativity of their users and enable an increasing number of people to be become involved in processes that previously were the privilege of professional designers. In effect, design is being distributed, becoming common, a way of living that challenges design as a separate profession.

These transformations significantly affect what kind of an information society will emerge and how design may be practiced in the immediate future. This report recommends specific actions that could not only make design a responsible partner in the development of future information infrastructures, as requested by NSF, but could also put designers in the position of leadership in an increasingly important dimension of technological development: the human, social, and even political dimensions of technology.

Our report addresses four areas and makes specific recommendations in each:

1. Predicting Technological Developments
2. Rising Technological Opportunities
3. New Design Principles
4. Designing Design Education
5. Key Research Issues

In addition, the reader of this report will find the results of discussions of five working groups in 6, a collection of papers that were presented during the workshop in 7, and several Appendices of related material. This executive summary sketches our recommendations in the four areas: predictions, design principles, educational implications, and research issues.

**Predicting Technological Developments**

Predicting the future of information and communication technologies is especially problematic because of short histories, simultaneous change, and parallel socio-economic forces. The Internet is the case in point. Nevertheless, predictions are important for designers in the 21st Century. Designers will need to understand the intricacies of communication, and think about how communication can enhance, affect, or constrain any process or device. We have divided our projections into three reasonably safe categories for the next seven to ten years: things that are inevitable, things that require some economic push, and things that carry economic, political or social baggage likely to delay or prevent implementation.

There are many political and business issues that will arise to affect design decisions, ranging from the lack of universal access to the unknown impact of future IT on travel patterns, alternative urban environments, physical shopping, manufacturing logistics, and employment. Understanding externalities beyond mere technological change must be part of a design profession’s toolkit. In general, it is safe to predict that isolation may become a design choice, not an obstacle to be overcome; nomadic or mobile computing will be the norm; inexpensive high-resolution, even perfect, imaging and video will be prevalent; and appliances and processes will be capable of interacting with their environment. Yet, a large amount of research is still needed to cope with the technologies we forecast, especially research on how humans process vision, sound and other interfaces — we still know very little about our own information capabilities. Furthermore, without some changes in the support infrastructure, many applications will simply not happen; missing infrastructure includes: cheap and modular batteries and power supplies; integrated network storage architectures; and a “decent” set of human interfaces and “plug and play” appliances. Finally, we assess technologies that can, but may not happen, and which may be critical to the implementation of others. Such technologies sufficiently threaten the status quo to be resisted, and others may become threats only after introduction.

**Design Principles**

One assignment that NSF gave to our workshop was to explore the principles that will govern design in the future and the research needed to make design a partner in national efforts to shape the next generation of information technologies. This report acknowledges the radical shifts in design practices from the industrial age, with its emphasis on the mass production of consumer goods and services, to an age of information, whose “products” are becoming more virtual, informational and intelligent; interaction with them is resembling language use more so than that of tangible tools; and their everyday accessibility is bringing more people than ever into communication with each other, into viable self-defining user communities. The design principles developed in this report do not merely respond to these shifts, they attempt to lead the ongoing revolution in the sense that failing to apply them would mean reverting back to outdated design practices.
Fundamental to these new design principles, and perhaps enjoying the widest consensus among the workshop participants, is the commitment to a human-centered approach to design. By this we mean an explicit emphasis on the human uses of artifacts, not on technology for its own sake; an acknowledgment of the need for user communities to understand and remain productive parts of society. This means assigning subordinate places to abstract and supposedly universal criteria of functionality, efficiency, and economy, all of which ignore the question “for whom?”

The following ten design principles are intended as recommendations to:

- **practicing designers** who intend to work on information products/systems/practices that are likely to be prominent in the next decade;
- **educators** seeking to prepare design students for roles in the ongoing information revolution and to develop new educational initiatives, including doing research to bring them about; and above all to
- **funding institutions** whose support of scientific research, educational initiatives, or development of particular information products should embody these principles in their RFPs and encourage their use so as to contribute, in however small ways, to the ongoing revolution in human information practices.

We recommend that all artifacts — material, informational, or organizational — be designed for and together with their stakeholders. Stakeholders assert a stake in the development, use, and disposition of a particular technology and are willing to act on it. This design principle seeks to overcome the industrial age emphasis on the lone “end-user,” “consumer,” “customer,” or “client.” The user was an abstraction that kept traditional designers unaware of the complex network of people needed to bring any design to fruition, and unaware of their own social/political role.

We recommend that artifacts be designed so as to make sense or be meaningful to their stakeholders. People do not respond to the physical properties of things but to what they mean to them. Meaning is axiomatic to design and semantics has become its overriding criterion. The industrial age took for granted the universality of design criteria. It positioned design in the service of industrial mass production and deliberately ignored cultural diversity. In an age of information, the multiplicity of users’ meanings matter in all design considerations, and affording them technologically is not only easier but is a condition for bringing rather different people into an information society. Accordingly, forms should not follow designer-specified functions but afford users’ multiple meanings.

We recommend that design be primarily concerned with interfaces between humans and their technology. Current information technologies have become unthinkable without the design of interfaces that translate the various human worlds into the causal and digital world of computation and communication. In the past, design has attended to this aspect of technology mostly as a sideline. Now it has become a priority, for no society can afford to render the majority of its population technologically obsolete. Human interfaces, in all of their many manifestations, constitute the unique empirical domain of design.

An essential achievement of information technologies is the provision of variability. We recommend that artifacts be designed variably, flexibly, multi-dimensionally so as to match or exceed the diversity of their stakeholders’ capabilities, needs, and conceptions. Information always affords multiple interpretations and the most outstanding feature of the information age is that more people with more diverse backgrounds, interests, and abilities, especially those previously considered “disabled,” can work together, and thus contribute to the larger society. The report discusses five technological sources of variability:

- Product differentiation
- Personalization
- Multi-pathing (including multi-media)
- Reconfigurability
- Adaptability.

We recommend that all artifacts be designed to enable cooperation, honor diversity, and support conflict. Network technologies already enable a kind of cooperation: communication. But these are still too simple to fully support and significantly enhance the
kinds of joint activities that constitute small groups, management teams, organizations, cultures, and political systems. Since cooperation can not be designed from the top down, it must start within the design process itself and create artifacts that encourage cooperation among subsequent users as well.

The artifacts of the information age differ radically from those of the industrial age. The old design principle of consistency of form and function has revealed itself as far too simplistic; architectural metaphors and logical hierarchies have proven themselves as too static; the model of social control has lost its motivational appeal; and uniformity and standardization have become unattractive. In contrast, we recommend that information products be designed *heterarchically, not hierarchically*, that they embrace many views, not one; that they be open to new and emergent descriptions, not be constrained by a common (and artificial) language; that they provide ample spaces for unanticipated uses, not be limited to a designated function; and that they enable virtual communities to arise, not be restricted to a privileged user elite. In our market- and increasingly information-driven society, systems that are too rigidly structured, closed to reorganization, or intolerant to some measure of chaos have mostly failed.

In an age of information, artifacts are not only more language-like in the sense of being freely recombinable and reproducible in different media, their genesis is more than ever tied to natural language use. Design teams receive their assignments in writing, negotiate their proposals by talking, and must argue for the virtue of their products in a language that needs to be compelling to those that matter for their design projects to succeed. In addition, the design community thrives on its ability to document and access design solutions and failures and to have a design literature of its own. Design resides in its discourse. We recommend that design researchers and product developers realize the linguistic nature of their efforts, document their processes publicly, make them available worldwide, and *demonstrate compelling evaluative techniques*.

We argue that human-centered design is *constituted in a second-order understanding*, that is, the designers’ understanding of users’ understanding. Accordingly, designers should be concerned not with technology as such, but with how technologies are being understood by diverse stakeholders. The understanding that engineers bring into their world is generally very different from the understanding users have of theirs. Designers have to embrace both. This means speaking not of particular products, systems, or practices, as if people had nothing to do with them, but of what such products, systems, or practices mean for those who interface with them. Research should address all stakeholders who might interface with a technology, not just the engineers of that technology.

**Design** is a body of expertise that information technologies must *continually disperse, distribute, and make available to non-professionals*. Desktop publishing has made obsolete a good deal of what traditional graphic artists did. Web pages are increasingly designed by users without special training. Computer hackers often exceed the competencies of trained software designers. The information revolution exhibits design as a universal human activity. Designers can do no better than stay ahead of those they work with, speaking a language that compels others to participate in processes of design, and asserting visions that reality can bear out.

We are asking designers, educators, and especially funding institutions to encourage practical projects and scientific research that apply some of these principles.

**Design Education**

Design education plays a central role in the development of future technologies. Those individuals who will be responsible for shaping tomorrow’s information systems and artifacts are first educated in our colleges and universities. An over-riding question the workshop attempted to answer was: If design is pervasive, who then is a designer and how is s/he educated? Furthermore, how flexible can our educational structures be in order to support, even nurture, new ways of teaching tomorrow’s designers?

New participants, new initiatives, and new thinking are needed if the design disciplines are going to be contributors to the larger picture of design in the Information Age. Change is imperative on three fronts. First, change is necessary in academia, not only within design education, but within programs that are potential partners in collaborative projects and research. Second, a change in thinking is needed within companies and institutions that may stand to gain from partnerships with academia in the form of sponsored projects or research. Third, change is imperative within funding agencies that fail to consider design programs at universities and colleges as recipients of major grants.

The discipline of design has much to offer to a collaborative process – principles, theory, methodology,
and a unique way of seeing the world and approaching problems. We therefore make the following recommendations concerning design education:

- When sponsoring project courses at universities and colleges, government and industry should specify that the work be carried out by integrated teams representing several disciplines, each relevant to the task at hand and able to address the many issues related to product development, design planning, production and implementation. This requirement will send a strong signal to academia and encourage new structures and new approaches to collaborative design.

- Governmental agencies, like NSF, and industry should play an important role by sponsoring major interdisciplinary projects focused on designing collaborative design environments, with real and virtual aspects. These environments would link researchers - students, faculty, and industry representatives - as they work on developing new collaborative technologies. Associated with this work should be research into the processes and methods employed for such collaboration, as well as the environment for collaboration itself.

- Courses that inform designers of human behavior (i.e., cognition, social/cultural factors, people and organizations, people and technology, evaluation methodologies) should become part of the design curriculum.

- At the conclusion of a major project, undergraduate design students should be encouraged to provide reports that document their design process. This task of reflection, collection, writing, and editing demands an objective point of view in pulling together a report that is informative to and readable by any interested party. Graduate students should contribute with a written thesis that attempts to broaden the current thinking and knowledge base of the discipline. Finally, each year, faculty should agree to write one paper, give one presentation, or participate in a public discussion that contributes to building this knowledge base about design.

- Disseminate current literature about design education to those within and beyond design programs. Then, convene an annual Design Education symposium devoted solely to the issue of educating the new designer, initially as defined by Simon. Content will focus on new thinking, new courses, research projects, and other activities that inform the education of this new breed of designer.

- NSF should fund projects that explore distance learning coupled with interactive technologies. The implications for content development, organization, and visualization, as well as technical delivery - divergent applications on convergent technologies as a goal - are aspects that need serious consideration. Equally important are implications of distance learning on learning itself, the quality of the experience, the resulting work, and student mentorship. Clearly, this is multi- and interdisciplinary work with representation needed from the fields of psychology, education, writing, design, film, and computer science, to name but a few key areas.

**Research Issues**

NSF also gave this workshop the charge to suggest research that, if supported, would not only drive the future information infrastructures in a human-centered way, but also make design a partner in these developments.

In making technological predictions, proposing new design principles, and formulating educational imperatives, this workshop has already demonstrated that design is certainly a part, but could become an even more central part, of information technological developments. We identify and outline below seven major research directions which could facilitate this process by promoting the reconceptualizations and systematic knowledge needed to drive the information revolution along a path of human-centeredness. Scientific research and developmental work in these areas could provide keys to tackling other issues, thus avoiding dead ends and making the best use of valuable time and resources.

These seven areas call for institutional commitments and include several actionable proposals. They might entail:

- Preparatory research support (to frame a challenge),
- Seed grants (to stimulate effective proposals),
- Implementation grants (to carry out projects),
- Integration workshops (to compare and assimilate results),
- Major collaborations (to put a whole system together).
(1) We recommend the commitment of resources to the systematic development of an alternative to the traditional paradigm of research, of a paradigm that is more responsive to the information technology that needs to be designed within the next decade. The traditional scientific research paradigm emerged during the age of the enlightenment, which was committed to the idea of mechanism and came to fruition in the industrial age. Research was re-search and meant searching the past, again and again, to find rules, laws, and empirical constraints that would outlast the present and determine the future. In contrast, design starts from a vision of the future and searches the present for possible paths to get there. Specifically, we request support to systematically articulate and elaborate a research paradigm — methodologies and justifications — for design which is committed to the ideas of participation and of making new artifacts possible, especially in the areas of information and communication. This initiative can accelerate technological development.

(2) We recommend a concerted effort to develop a second-order science of the artificial. The idea of a science of the artificial had been articulated by Herbert Simon, who wrote in the 60s when today's developments in information technology were beyond everyone's horizon. This science must be expanded to embrace the diverse ways of understanding that stakeholders, users as well as engineers, bring to this technology. Research into the dynamics of understanding technology is qualitatively different from research into technology itself.

(3) Together with a new paradigm for research and a second-order science of the artificial, a semantics of interfacing with artifacts is the third leg on which the ongoing information revolution can rest assured of its future. Product semantics has made the design of human interfaces that are natural, self-evident, easy to use, intrinsically motivating, and accommodating of multiple cognitive models a central issue for human-centered design. We propose to

- develop a dynamic and interactive semantics, a theory of meaning and sense that arises from experiences with human-computer interactions rather than from systems of representation, such as signage.
- advance a stakeholder theory that replaces the old consumer/user model with a network of active, well-informed, and intrinsically motivated stakeholders in a particular technology.
- expand the vocabulary of product semantics so as to be applicable to a wider range of "products:" virtual, informational, and organizational.
- formalize practical design methods that build diverse stakeholders' understandings into the design process.
- improve analytical techniques and measurements of meaning to a level of rigor comparable with that in engineering.
- organize conferences and workshops that address practical aspects of semantics in an age of information.
- publish research, practical results, and text books on the new semantics.

(4) Multi-disciplinarity has been a key issue in this workshop, largely because information “products” are so complex that they cannot be conceived and realized without collaboration across disciplinary boundaries. We recommend that a multi-pronged research effort be launched to develop both the processes and technologies that could support multi- or inter-disciplinary collaboration. We propose:

- Networking design centers into collaboratories. One proposal is to develop a virtual design institute; another is to link educational programs so as to improve the quality of educational resources for all of their participants.
- Designing collaborative software. Collaborative software is available but largely unsuited to how designers work, especially in collaboration with other highly intelligent and creative experts.
- Developing collaborative procedures that can be taught to and enacted by people working together – whether they improve collaboration among all kinds of people or inspire new (collaborative) technologies based on their experiences.
- Exploring techniques for attracting stakeholders into a design process. Many people that have a stake in a technology will assert their interest but not become involved in the design process without some facilitation.
- Enabling future kinds of citizenship. Notions of citizenship are currently limited largely to voting. Information technologies are bound to radically transform the political process. It is of paramount importance to develop systems by which people can realize themselves as political actors and effectively participate on many levels of government.
We recommend research into more suitable conceptions of information. The old consensus (on Shannon’s theory, for example) has faded without a new one in sight. Although the ambiguity of the word “information” has served the information revolution well, bringing together many technologists, designers, visionaries, and enthusiasts, we will need a better grasp of what we mean by information if we want to create future information technologies more deliberately, that is by design. In the report we outline some of the properties of information on which an information society may be constructed. We propose research to reconceptualize information interactively, dialogically, and realistically, and to develop theories of how information technology is related to its human users.

Ambiguous conceptions of information may stem from looking at the new technology from the wrong angle. It is conceivable that the real benefit of this new technology lies not in the information it promises to nearly everyone, but in the coordination it provides: the coordination of personal activities that gets work done; the coordination of people that constitutes social organizations; the coordination of material entities that creates technological complexes such as industries; and the coordination of economic variables that makes for profitable business enterprises. This understanding of information technologies in terms of coordination is new and needs to be explored; we recommend that research be directed to the development of theories of coordination, the kind of coordination that the new technologies enable.

In order for design to justify its value, it needs a vocabulary and compelling arguments which can convince stakeholders that their stake is worth the efforts asked of them. Most established disciplines, such as engineering and medicine, can test their proposals or have elaborate techniques to evaluate their products before they are used. Developing evaluative techniques for the design of information systems presents considerable challenges which our report addresses. In as much as the design of such systems requires the participation of many people, reaches further than ever into the future, and involves higher risks of failure, the need for evaluative techniques is ever more pressing. Therefore, we recommend support for research on the development of criteria that information technologies must satisfy, and of evaluative techniques that are both rigorous and compelling — without deviating from the human-centeredness of design.
1.0 Overview

In his *The Sciences of the Artificial*, Herbert A. Simon recognized:

Everyone designs who devises courses of action aimed at changing existing situations into preferred ones. The intellectual activity that produces material artifacts is no different fundamentally from the one that prescribes remedies for a sick patient or the one that devises a new sales plan for a company or a social welfare policy for a state. Design, so construed, is the core of all professional training: it is the principal mark that distinguishes the professions from the sciences. Schools of engineering, as well as schools of architecture, business, education, law, and medicine, are all centrally concerned with the process of design. (Simon, 1969: 55-56)

Even Herbert Simon, an early pioneer in computing and major generalizer of the conception of design, could not envision the explosion of information technology we are now facing. What happened since he wrote these words amounts to the emergence of a new kind of technology, a new kind of society, accompanied by an unprecedented shift in the quality of life for nearly everyone. This shift turns out to be far more global, instantaneous, and fundamental than that initiated by earlier major inventions, printing, telephony, radio and television, for example. A consistent trend of these inventions is that more and more information has become available, now growing exponentially. Larger and larger spheres of life are becoming known, coordinated, and reorganized, often leading to increased prosperity. We are in the midst of a cultural revolution whose directionality we do not fully understand and whose end is not in sight. Notwithstanding prophesies of a golden information society, our current vocabulary is insufficient to articulate clear design goals for such a society. This motivated the National Science Foundation to fund a workshop that could develop some recommendations for design in an age of information.

The trajectory of artificiality we can construct from products to discourse (see Krippendorff in this report) can measure designers' responses to these technological changes. Along its course, designers are asked to transcend their initial concerns with surface appearances and increasingly address issues of meanings and identities, computer interfaces, multi-user information systems, cyberspaces, socially viable projects, and discourses for designing design, whose materiality is far less obvious yet of considerable social significance. Such
problems challenge our conceptions of design practice, design education, and the identity of design as a profession.

Changes of this kind can not be understood in terms of causes and effects. Already Herbert Simon pointed to the inadequacy of naturalist logic. “Design” he said, “is concerned with how things should be,” not with what they are (1969, pp. 58-62). What we are thus facing is a crisis in conceptualizing where we want to be and how we should proceed. Our fascination with the leading technologies seems to fuel four “world altering transformations:”

- **Digitalization** has a long history of making more and increasingly smaller units able to be manipulated individually and at staggering speeds: the pixels of visual images and the states of atomic mechanisms, to name just two. Digitalization has done two things. It has dramatically increased our ability to implement algorithms and thus altered the world of objects we can now construct. It also virtually exploded the design space (the number of options) we are facing today — not just as professional designers but also in everyday life. Different forms of life have become realizable, calling for unfamiliar criteria.

- **Networking** these units across time and space has also progressed at an unprecedented rate. Never in human history have so many humans been able to know something of each other, respond to each other, communicate with one other over distances they could not possibly travel in a lifetime, and access far more information than they can possibly process. The library that served as a metaphor for knowledge during the Age of Enlightenment is now being replaced by very large multi-user information networks.

- **Equity of access** is quickly becoming a political challenge for design. During our Enlightenment past, equity (fairness, impartiality, and justice) became part of our democratic ideals that industrialization could never quite deliver. By contrast, the emerging information technologies have in common that they work most efficiently when access to them is universal, information is freely shareable, and geographic, social, cultural, and language boundaries are no longer in the way. This makes information technology a partner in the development of a new kind of society, a new kind of citizenship, a new kind of commerce, and a new kind of scholarship. The condition for achieving equity of access for everyone means nothing less than reversing the time honored direction of influence from technology to culture by putting human-centered attitudes in the driver’s seat. The major task for design in the decades to come is to develop information technologies that are, at least at their human interfaces, readily understandable by different users, responsive to a multiplicity of needs, affordable by everyone, and operable under any condition.

- **Dispersion of design.** A natural corollary of the above is that an increasing number of people are becoming involved in processes of design — from desktop publishing to tinkering within the net. The widespread realization of these technological possibilities has virtually replaced the ideal of the lone genius/designer by that of informed and passionately engaged communities of stakeholders in a particular technology. In an age of information, designers can no longer be masters in all aspects of a design, they have to be experts in the human use of technology and be able to work in multi-disciplinary teams.

These four intertwined transformations are ushering design into the next century. This report suggests some paths for designers to take, for educators to embrace, and for foundations to support.

### 1.1 NSF on Design

Ideas abound for developing a national information superhighway, a national information infrastructure, a US citizen network. Such developments may be too big to be undertaken by small research and development teams working with their own resources in a corporate or university environment. The success of the Internet, which traveled from a military application through academia to the public sphere, attests to the fact that it is the commitment of large scale and long term support that can bring such ideas to fruition. The National Science Foundation probably is the most important funding agency for scientific research and development of its kind and is in a unique position to bring research groups from different disciplines into collaborative efforts that could further some of these ideas.

NSF posed these questions to our workshop:

- What can design contribute to the information revolution we are experiencing, taking a citizen/user point of view? and
- What can the Federal Government do to support relevant research in design?
Gary Strong, Program Director for Interactive Systems at NSF, gave a presentation to this workshop in which he outlined his conceptions in terms of where we are, where we would like to be, and what we need right now to get there. The following summarizes his points:

Where are we?
- The existing information infrastructure is still rather limited and does not yet impact on society as a whole.
- There is considerable inequity between heavy users of available information technology, amounting to an emerging information elite, and the vast majority of the US population that do not access computer mediated information services.
- A variety of multimedia have emerged that promise to expand ways information can be provided, but we have no adequate concept of information nor a good sense of the architecture to pursue.
- New devices, such as laptops, palmtops, and desktops are entering the market and have the potential to revolutionize access.
- Current interface developments integrate QWERTY keyboards with point and click interactions. Experiments with voice have shown only modest results.

Where do we want to be?
- High capacity, reliable, and multi-modal communication networks that link available information resources to people in homes and offices everywhere and are affordable.
- Ordinary citizen access to information and education, anytime/anywhere/for everyone, not just for an information elite. As we achieve universal access, we need new forms of citizen participation in government.
- Multiple channels of information, linked computational resources, and innovative media that support many and different kinds of human interaction.
- Devices that are small, portable, or reduced to an efficient interface.
- Interfaces that are natural, almost as easy to use as talking with someone, without requiring extensive learning. Users would be able to grow up with such technology and end up considering their role in everyday life self-evident.

What do we need to get there?
- We need to know what designers can do expertly and in which way they can help us shape the next generation of information technologies: the principles that govern design in the future and the research needed to make design a partner in these developments.
- We need to know how we can help design to make the contributions it can, whether by financing programs for developing new approaches to design, supporting new educational initiatives, or underwriting research projects that are likely to move the national information agenda ahead.
- We need a tangible report to carry the results of this workshop to those who could not attend and to make a compelling case for supporting future workshops that continue the conversation on design in an age of information.

1.2 Workshop Goals

Acknowledging the difficulties of predicting technological developments much beyond, say, ten years from now (see 2.0 in this report), the workshop participants were asked to work backwards from a plausible image of what society could be like in the year 2006 (see Justice in this report) and consider the design principles, semantics, methods, techniques of evaluation, collaborative forms, and education needed to get there.

The following workshop goals were developed:
- Create a coherent set of information design research education topics and discuss possibilities for their development over the next decade.
- Build a set of design principles, semantics and methods for improvement of information systems.
- Present critical theory, evaluation and measurement as strategies for information systems development.
- Promote interdisciplinary working relationships for information systems development.
- Stimulate new projects involving information systems.

To accomplish these goals, this workshop addressed the following themes for paper submissions and discussion.

1.3 Initial Targets for Discussion

A way of being in 2006. The evolution of information systems over time will inevitably change our expectations of technology, the culture that will use it, the occupational structures within which we are likely to work, and the professional and ethical responsibilities of
these new designers. To provide a context for thought and discussion, we hope to develop possible scenarios for the evolution of information systems over the next decade.

**Background knowledge and disciplines for future practice.** The education of interface designers will have to draw from numerous areas of knowledge normally available only to specialists. What are these knowledge areas? Which disciplines? How are they to be combined and applied in the design practice settings of the next decade?

**The Structure of Future Education.** Information technology and the widespread networking of knowledge resources are changing education, changes which themselves affect the education of these new designers. The needs of universities, business, industry and individuals must be reconsidered. A new set of educational objectives and methods for achieving them must be developed, justified, and implemented. What will the research agendas be and how will they be funded and carried out? What new opportunities and challenges will result from potentially valuable partnerships among academia, government, business and industry?

**Identifying New Design Principles for an Information Age.** The design of products and the design of interfaces require different perspectives. Interactive semantics, self-instruction/motivation, delegation of design to users, language-like artifacts, methods of assessing the efficacy of interfaces and user-centered understandings of information needs are some of the principles that change relative to differences in perspective.

**Collaborative Development Environments.** Networking information resources to coordinate design such as concurrent engineering, group works, and management tools for research and development teams, will redefine anew how design can work in an interdisciplinary manner, in real time, and at distributed locations.

**Design Discourse in an Interdisciplinary Setting.** In the new design setting, previously separate disciplines will be brought together. Information systems developers may work with sound designers, data architects, film makers, educators, graphic artists, etc. New alliances will also be formed between customer and designer, with some users taking increasing responsibility for design and development. How will these groups communicate? How will we find common conventions for discussion, communication and understanding?

**Promoting scholarly publication by designers of information systems.** Many disciplines are publishing and sharing new knowledge. Designers need to participate in this research, development and publication.

### 1.4 Organization of the Workshop and Report

The participants of this workshop were all invited for two and a half days, from February 29 to March 3, 1996, at the Microelectronics Center of North Carolina (MCNC) in Raleigh, North Carolina. Fifty-one participants from Government, Industry, and Academia came and gave a total of approximately 32 short presentations the abstracts of which had been circulated in advance. The presentations to the whole group and subsequent discussions of the topics raised by them were followed by smaller meetings of four separate working groups, designed to develop recommendations on specific issues. A fifth group emerged on its own. Seven students took copious notes and taped these working group sessions to provide a basis for this report.

This report is an effort to publish the most important of these recommendations and to contribute to the debate on the role of design in a society that is no longer dominated by a concern for consumer products but by information. Recommendations were culled from numerous notes, tapes, and papers and reorganized by the authors of this report who wrote individual sections. Their names appear on the title page. Since this writing took longer than expected, our report not only summarizes what transpired during the workshop but incorporates new insights and addresses further developments as well.

In short, the report presents a series of recommendations on four key issues raised by NSF regarding Design in the Information Age: Rising Technological Opportunities, New Design Principles, Designing Design Education, and Key Research Issues. These are followed by more detailed comments and some specific proposals that emerged in the working group sessions which are in turn followed by some of the workshop papers.

Due to the volume of ideas and materials this workshop generated, there had to be omissions and differential emphases that reflect the biases of the authors of this report who assume responsibility for any inadequacies that its readers might discover.
1.5 Steering Committee

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Simon, Herbert A. The Sciences of the Artificial.  
2.0 Predicting Technological Developments

Predictions depend on the assumptions one makes regarding the trajectories into the future. Picking the starting time point can be especially critical; do we start projecting a trajectory from today's knowledge base, or do we pick some point in the past for an origin? Is there a reasonably documented history? The choice of the time frame is important as well; are we talking of five, ten, twenty, or fifty years from now? The farther we look into the future the more uncertain it appears. With each iteration, uncertainty enters and accumulates rather than diminishes. Perhaps most significant is the choice of the model being used to extend the process into the future; can we assume changes to be regular, inevitable, and hence projectable by linear extrapolation? Or do we have reasons to assume changes to be non-linear, dependent on unknown or unpredictable externalities, or on complex and intractable interactions? In the latter case, after several iterations of such predictions, quite literally, anything (or nothing) might happen, chaos reigns, and forecasting becomes just a blind guess.

Predicting the future of information and communication technologies is especially problematic and far more difficult than predicting the trajectories of relatively simple technologies.

- Many of these technologies are unprecedented, have only very short histories, or rather tenuous connections to the histories of other media.
- Communication has been growing far faster than our systematic knowledge of it. Nobody can keep up with these developments, not even the entrepreneurs that drive them.
- Communication is intricately linked to networking, and networks — whether transport, electrical, or human — are inherently messy. Communication networks are massively parallel and essentially consist of interactions between the processes they connect.
- Changes in information and communication technology occur in so many dimensions simultaneously that confusion often reigns in the predictive process.
- Information is linked to the conceptions users bring to it — as communication is linked to the conceptions people have of each other — and this simple fact connects the use of this technology to
individual cognition, to social relations, and to user cultures whose developments are even less predictable.

The Internet, as almost everyone recognizes today, is the case in point, encompassing social, economic, and political forces as well as technology ranging from the spread of distributed processing to drastic changes in global telecommunication provisioning.

In the past, predictions of technological progressions, even of technologies that do not exhibit the complexities of information and communication, have been notoriously wrong, even (or perhaps especially) by people who are recognized experts in their areas. To better understand this historical fact, we need to draw finer distinctions among the technologies for which predictions are sought. For information technologies that are already on the shelf in laboratories, predictions are relatively safe, especially when one limits the time frame of one’s predictions to the next seven to ten years. Under the assumption that such changes or progressions are inevitable and determinate, predictions may be made by extrapolating past regularities into the future. These are the easy predictions. For other areas of information technology, already after a few iterations, chaos reigns supreme because the extrapolations may be non-linear, implementation depends on other things happening (which may also be non-linear), or all of the above. Even the educated guesses of experts in the field often are hopelessly wrong and technological developments are full of surprises. We will examine examples of both and let the reader decide which path she or he wants to follow.

Processor chips, for example, have shown a straight-line density relationship over the past 30 years, with no order of magnitude surprises. So, it is reasonable to predict gigahertz processing speeds shortly after the Millennium, and assuming investment in chip manufacturing does not cease for external reasons, quadruple today’s density within a decade from now. Should parallel processing become practical, which has more to do with software and application-specific devices than with chip density, then an order of magnitude change in processing “power” may be expected to go along with increased processing speed in a decade. This contingency is an example of the risks of non-linear prediction, for parallel processing may take several forms and would make a number of novel, powerful applications feasible, yet feeding back recursively and even chaotically on specific predictions.

While we may realistically prognosticate on processor chip capabilities 10 years hence, just how the chips may be used enters the realm of the unknown because of externality not within our predictive skills. It involves social and political processes that depend on public knowledge of this technology and move in the direction of second-order understanding (see 3.8 in this report). Therefore, our firm forecast on processor power is only moderately useful in assessing design needs for the first decade of the Twenty-first Century: yes, we will almost certainly have vastly more powerful computers, and yes, such things must have some impact on daily life, but exactly what processes will take advantage of these processors are yet to be determined. Looking backwards, we could have made the same predictions for the Arpanet evolving into the Internet in the early 1980s: most everyone could predict (and did) that the more powerful chips of the 1990s would certainly affect future data communications, and that “intelligence” in data terminals of the 1990’s will permit data networks to do interesting things beyond just email — pictures, for sure, and better database searching.

But, even had this technology been under control, how could we have known how the political and economic spheres would evolve to turn the public Arpanet into the private Internet, put PCs into 40 (?) million US homes, or create a hypertext graphical-user interface (HTML) web browser using a modified form of Arpanet file-transfer command (HTTP)? How could we have predicted some 15 years ago with any useful level of detail the impact and penetration of the World Wide Web and its user community, or the controversy over Internet pornography, or something so obscure yet vitally important as domain name registration? Moreover, to further confuse crystal ball gazers, in the early 1980s the environment from which predictions were made consisted of a massive hype for Teletext and Videotex which eventually failed miserably in the marketplace, and the mixed blessings of the French-government-subsidized Minitel, to boot — all essentially Internet precursors that led to dead ends.

A more specific example may illustrate why accurate knowledge of the future of a technology may not yield entirely useful foresights. Parallel processors-on-a-chip would permit designing a super-high-resolution electronic camera that not only captures an enormous number of photons in rapid succession, but also analyzes and enhances an image and does selective compression simultaneously onboard the image pickup device. Such an imaging appliance — an extrapolation of some bulky but similar devices which exist today in the lab as proof of principle — would yield a full-motion display which would resemble reality (or at least give the illusion of looking through a window at a real scene without imaging artifacts); with this chip, potentially...
available within a decade, a device would be small enough to fit in one's hand or mount inconspicuously, cheap enough to be produced for a mass market, and its compressed data output could easily be transmitted over ordinary telecommunication circuits. Now, this may sound to the reader as either a reasonable extrapolation of current technology or utterly fantastic, but, whether the technological predictions are accepted or not, each phrase is loaded with assumptions: e.g., what parallel events would have had to take place to define what an "ordinary telecommunication circuit" would be at this future point in time? What applications would such a device be used for — teleconferencing, surveillance, medical diagnostics, entertainment — and how would this affect everything else? The variations become much too speculative too quickly to make anything but the roughest guess about the future: a simple one, such a chip and such an imaging system will mean ten years hence we will have more full-motion, high-resolution images in all our applications. Pictures will be everywhere. Maybe.

Rather than become just a grab-bag of not very useful projections — eventually, one could argue, everything that does not violate the fundamental laws of nature becomes possible — we have divided our projections into three categories that a reasonable person can accept for the next seven to ten years. These categories are intended to help plan courses of study, and topics to be investigated, in any potential program for 21st century designers. These will be the technical tools, and in some cases the economic and social parameters, that designers are expected to be familiar with in this time frame.

Beyond that, the history of recent futures tends to show that predicting the things that will happen, the things we will have to know to be productive designers, and the things that will have to be researched is but a guessing game and often confounded by hypes, hopes, and unfounded beliefs. A decade ago, virtually no one forecast the penetration of the Web, despite the Internet just being formed with glorious predictions of its usefulness for the research community. Yet the principles of the hypertext pointer were recognized, and the power of its concepts readily accepted as far back as World War II — though few communicating dp systems had used them. No breakthroughs, no dictates made the Net (as opposed to other, less utilitarian "nets") happen; the Internet, after all, is just the gradual accumulation of clever software, "internetting" protocols, and a sudden surge for what, to us in 1997, was an obvious latent demand for a wide range of information.

The Internet is an excellent example of why predictions are hazier than ever, despite our knowing more than ever. There really is no Internet except in this virtual sense. It is a useful metaphor. Moreover, no single individual or agency made the Internet happen. It is still a work in progress, a work that is carried out by millions of users, hackers, and software designers. Today, nobody can say with any degree of precision what changes will take place 15, 20 or more years from now and when. Technological breakthroughs, as significant as a computer-on-a-chip, have to be factored into any projection made from today's knowledge of technology.

With these caveats in mind, to get at least a temporary handle on the various technologies we want to predict, we suggest three categories of "things:"

- Things that are inevitable, because (i) the technology is already on the shelf if not yet implemented in a widespread manner, (ii) its costs are reasonably well understood, and, most importantly, (iii) there is a demonstrable demand for it, however latent;
- Things that are possible and can be implemented because they are derivable from existing technologies, but would require some economic push (i) from either conventional engineering or a reasonable breakthrough, whichever comes first, and (ii) from a demonstrable demand; and,
- Things that fall into either of the two categories, but carry certain economic, political or social baggage that are likely to delay or prevent implementation.

These three categories constitute the columns of our table of future information and communication technologies.

One example of a technology that would be technically easy to implement, and which would have a significant impact on the evolution of electronic commerce, among other applications, is perfectly secure, untappable and unbreakable public-key encryption. However, a variety of political, social and economic interests are not only opposed to such technology, but have the power to prevent its widespread application. Understanding this, one must plan and predict around such futures where communications may never be totally secure. Even good or different design may be fruitless here if the socio-political environment puts undue constraints on implementation.

We further divide the above three categories into

- Technologies that would make a critical or significant difference (if implemented
### The Future of Telecom & Information Technology

*italic underlined = critical for progress; italic = semi-critical*

<table>
<thead>
<tr>
<th>Inevitable:</th>
<th>Economic Push:</th>
<th>Will be resisted or blocked:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost per bit, cost per instruction, approach 0</td>
<td>Batteries/Power</td>
<td>Privacy/security/authentication</td>
</tr>
<tr>
<td>Transducers of all kinds (micromechanics)</td>
<td>Storage architecture (may be resisted)</td>
<td>Open architecture/systems</td>
</tr>
<tr>
<td></td>
<td>Education (design and architecture)</td>
<td>Electronic money</td>
</tr>
<tr>
<td></td>
<td>Reliable systems</td>
<td></td>
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<tr>
<td></td>
<td>Trusted systems (certificates)</td>
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</tbody>
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#### Communications

*Packet switched everything*
- Public packet-switched network
- ATM/IP merge - PSTN/Internet merge
- Asymmetric Broadband tethered
- 100x decrease in transmission cost
- Untethered baseband
- 2-way LEO satellite - Full Earth coverage

| | Nomadic computing (symmetric and asymmetric, untethered broadband) | Convergence between entertainment & data networks/appliances/software |
| | Symmetric Tethered broadband | Universal service |
| | | Symmetric cable |

#### Human Interface

*Decent human interface*
- Voice Recognition & Authentication
- Decent human interface
- Plug & Play
- Intelligent agents (but will probably be resisted)
- Indexing and search
- Content-based retrieval (fuzzy)
- Electronic paper

*Language translation*
satisfactorily, whatever that may mean to the reader), that is, technology that affects the further development of technology, and

- Technologies that may have less impact on their own or other technological developments, which we term "semi-critical."

In our table of future information and communication technologies, semi-critical technologies are in italics, whereas those that make a significant difference for progress are in italics and underlined as well.

For example, such things as putting all communications on a public packet-switched network would manifest a significant change in the way devices and appliances communicate, as the Net and the Web have already demonstrated for a smaller segment of the market. Large (above 42” diagonal), high-resolution and cheap flat video panels appear inevitable and might make imaging ubiquitous, especially coupled with cheap packet telecommunication. So, with telecommunication and processing costs falling to zero at the same time as both telecommunication bandwidth and processing speeds accelerate (though not necessarily at the same rates), widespread symmetrical video can be readily postulated. Universal access is somewhat less likely. This leaves open what segmented, variable, or inconsistent access will mean for the designer.

Whether universal, high-quality, reality-based videophone would change travel patterns, generate different urban environments, replace physical shopping, create or reduce jobs — eco-political conditions permitting — is anyone’s guess. But, based just on current technology, one can certainly forecast that we will get large panels and cheap, broadband packet telecommunication. What happens after that depends on other parallel technological developments and especially on socio-political externalities which are much more difficult to project.

Broadband communication into the campus (which we have now, basically), into the large office, and very likely into the middle to upper income suburban home also appears inevitable; Latent interest for this technology is evident in the demand for highspeed Internet access alone. Several candidate technologies are being demonstrated for these select environments today and at acceptable entry costs — copper pair gain (xDSL), cable modems, cellular digital radio. But symmetry is an economic open question, and universality both an economic and political question; rural, inner city, and low density areas may not necessarily get equitable service. Low Earth Orbit satellites are technically feasible, but not yet economically proven.

Political constraints on LEOs have yet to be tested. Designers may be able to play a role in encouraging these changes by focusing on the economic and social parameters that directly affect penetration.

All of these predictions have a direct bearing on what could be the most powerful change in computing and communicating since the advent of the PC and distributed processing in general: truly nomadic, or mobile computing appliances, connected universally in space and time to the Net at direct memory access speeds (implying some form of symmetric, broadband radio communication). Will communication follow an implementation curve that further segregates users in space, time, and function, or will the externalities (for there are almost no geo-technical barriers to ubiquity with LEOs) encourage homogeneity? We do not know. All three of our columns in the table have a bearing on this question. Designers will often have to recognize whether social or economic mobility is enhanced or constrained by choice of technologies.

To summarize across our rows, columns and cells in our table, the most important predictions about information technology within the next ten years that may affect design education are that:

**2.1 Connectivity**

All devices will be capable of being connected to the Internet (or an inter- or intra-net), whatever architectures this will encompass — if not “untethered” via radio, then at least via wires. It will be so cheap to add communication interfaces to all processing chips (which already communicate internally by definition), that such input/output can safely be predicted to be part of the standard connector package. Not all chips will have the external I/O modules burned in, but they will be available if wanted or when needed. That alone is a revolutionary prediction. Isolation will be a design choice, not an obstacle to be overcome.

**2.2 Communication and Processing Costs**

Packetized, broadband channels are less likely to be universal, but for large segments of the interlocked global economy some form of broadband data access will be available. Communication costs (especially for narrowband) will drop so low that voice and low-speed data communication will not be a barrier for virtually any implementation. Processing costs will approach zero as processing speeds run into the gigahertz range.
Designers will need to understand the intricacies of communication, and think about how communication can enhance, affect, or constrain any process or device.

2.3 Imaging

Imaging, video and its derivatives, will be prevalent on these networks, cheap and with improved processing at qualities comparable to that of 35mm still cameras today — but with moving images. Compression will permit symmetrical delivery at data network speeds that will be common in the future. Humans are very visually oriented; yet some segment of the population cannot use vision, and a large segment is visually impaired one way or another. This makes the translation of images into other kinds of interface media a challenge to design (see 3.4, 3.5 and Koncelik in this report). The tools to use images and enhance vision are just evolving. Designers will not only have to understand images and imaging, but will need to understand how humans see — something even experts know very little about today. Technologies of transmitting images and to some extent manipulating them are far ahead of the knowledge we have of human vision. Perhaps, today’s imaging technology is not even relevant to the human needs. Here designers may have very different points of view.

2.4 Sound Processing

Future sound processing will be capable of adjusting to ambient room characteristics, variable human hearing parameters, and be capable of understanding and authenticating voices. Drastically lowered processing and transmission costs, as noted above, will permit commercializing existing audio technologies that enable advanced sound processing, making this the easiest of predictions for the next decade. But, as with imaging and vision, we still know very little about human hearing — not on the level of acoustics but on the level of cognition, selective suppression of voices, sound-pattern recognition, and correlations of sound with other sensory experiences. Yet for the hearing impaired (which to some extent includes all of us at some age bracket) although we have had the capabilities of overcoming some key aural handicaps for a long time, designers of audio-based interfaces tend to think only about linear, distortion-laden gain control and rarely about human sensory sound envelopes and room ambiance. This knowledge gap needs to be corrected if multimedia are to replace the current mono-media emphases.

2.5 Miniaturization of Transducers

Tiny devices responsive to acceleration, vibration, motion, heat, etc., will be as common as processing chips, and will be equipped to react to human behavior as well as to various physical parameters. Their low data rates will ensure that most of these devices will telecommunicate, likely by radio or non-wireline methods, with applications ranging from traffic control to the continual monitoring of structures, bridges, buildings, etc. Again, the designer will need to look at devices and processes from the view of interaction with wide ranges of environmental factors, for example temperature, humidity, air pressure, human and animal proximity, external and internal stresses, corrosion and decomposition, and geographical location, instead of just in select isolation.

2.6 Technologies in Need of Stimulation

Several critical technologies will not be inevitable unless there is some sort of economic stimulus. These are technologies for which laboratory data and demonstration projects indicate no physical or knowledge barriers to implementation, almost everyone agrees on the necessity and the existence of demand, but the risks involved in specific implementations are too high. These include: modular and powerful, lightweight and long-lasting, cheap (and environmentally sensitive) batteries; storage architecture integrated into the Net and Web hierarchies; and a decent set of human interfaces and “plug and play” appliances. Without some changes in the support structure for these technologies, many applications will simply not happen. Economic burdens, the complexities of developing the technologies involved, or the inconveniences of pursuing certain developmental paths act as disincentives to developing them to the point of market entry. Interestingly, many of the barriers to implementation are in essence exercises in design, in particular interfaces.

2.7 Technologies that can but may not happen

We discussed the first two columns of our table somewhat intertwined with each other. The third column is different, however, and could be disturbing to some futurists. Some good, solid technologies may simply not happen within the ten-year time frame we are addressing for a variety of non-technological reasons — despite the fact that these technologies may be
critical to the implementation of other more mundane technologies. We have already mentioned secure transactions. Somewhat related, but with a different set of problems, is electronic money. Anything that changes the way money is transferred, tracked, and most importantly, created, impinges upon the basic sovereignty of the state and its fiduciary responsibilities. Small amounts of electronic money can be ignored. But large transactions, either individually or cumulatively (a small fraction of an extremely large number is still an extremely large number) can have an impact on the monetary system as a whole. No government or central bank is going to allow full-scale electronic transactions without strong levels of control. On the transparent international level of the Net, this could be a nightmare. Since it took the world economy 400 years to understand how paper money works, and occasionally it does not work well, it is not likely that electronic money will enter the daily level of net commerce smoothly or ubiquitously any time soon.

Other technologies may not be carried to fruition because they threaten the status quo sufficiently to be resisted. Similarly, other technologies can be expected to develop into major threats. However, such threats are neither inherent nor initially obvious, but become evident only after other technologies have become available. Such are the problems of omniscience in forecasting.
Design principles are propositions whose truth does not lie in the past but in their ability to guide actions toward desirable futures. Design principles have to acknowledge a present environment (of technology, information, people, and institutions) in which they are to work and meet their reality. But they must also lead beyond it and challenge what would happen anyhow. As such, design principles are heuristics that will have to prove themselves in future oriented practices.

The following attempts to extract several such principles from the contributed papers and discussions during the workshop — always in the context of the emerging information technology we are facing.

3.0 The Role of Stakeholders/Users in Design

Artifacts — material, informational, or organizational — should be designed for and together with their stakeholders. Stakeholders assert a stake in the development, use, and disposition of a particular technology and are willing to act on it. Stakeholders may be of various kinds: producers, researchers, engineers, sales persons, bystanders, advertisers, journalists, particularly including different kinds of user groups. Even designers always are stakeholders in their own right. Much as with major ideas, the fascination with particular kinds of artifacts brings interested parties together and transforms them into networks of involved participants that in turn realize these artifacts. Without support from various stakeholders designers accomplish little. Technology drives nothing by itself, people do (see Roth in this report). The repeated demand for “user-centered design” and the idea of defining designers as “advocates of the end user of a product” affirms this design principle but conceptualizes it in terms of the outdated distinction between production and consumption and encourages a lopsided loyalty. The artifacts of an information society are not as solid as those in an industrial society. They continuously evolve, transform themselves in the hands and minds of rather different people and reside in processes or practices, not in fixed products for single users. In an age of information, designers must be able to work with all those who care to be involved, each for their own reasons. This design principle replaces the industrial age
abstractions of the “end-user,” “the client,” or “the consumer” by a network of actively involved stakeholders who can bring a design to fruition.

3.1 The Axiomaticity of Meaning

Artifacts should be designed to make sense or be meaningful to their stakeholders. Product semantics has long recognized that people do not respond to the physical properties of things but to what they mean to them. This insight has lead to an irrefutable axiom for design:

Artifacts never survive within a culture without being meaningful to their users (Krippendorff, 1995).

Starting from this axiom, product semantics is developing theories of meaning, a vocabulary, design methods, and evaluative techniques for designing artifacts in view of what they mean to stakeholders, especially users, of products or systems, and how they perceive, handle, utilize, and talk of them (see Butter and Krippendorff in this report). This design principle speaks against the tradition of letting artifacts be driven by technology or of having to create experts for using a particular technology. Self-evidence, self-instruction, a natural path to competent use without special training, sustained engagement are some of the aims of product semantics. Developments of computer interfaces have taught us that meaningfulness and compellingness are central to the design of intelligent products or systems which may not and need not be fully understandable by their users. The 19th century design principle “form follows function” is no longer applicable. Instead, forms must afford users’ meanings.

3.2 The Centrality of Human Interfaces

Design should concern itself primarily with functional human interfaces. For designers, artifacts are of interest only in so far as they afford their use. The conceptual models that user communities bring to a product or system are far more important than how it functions and the architecture that lies behind its construction. For example, computers are far too complex to be understood by ordinary users and even more so are the information networks through which we communicate quite well. Unlike traditional tools whose technology (composition, function, and production) and use made perfect sense to most of us, intelligent artifacts embody many separate knowledges, none of us can master in their entirety. In fact, the gap between these expertise is widening rapidly and forces us to realize that the question of what an artifact objectively is, is secondary to how we can interact with it. Intelligent artifacts should be designed so as to be approachable and useable with conceptual models that are already available in the population of their users or easily acquirable by them. The point is to design systems that allow people to behave more like people (see Henderson in this report) and feel comfortable with them. Wherever a technology is too complex to be comprehended, this means inventing interface engines that bring that technology into a world users can understand naturally and find engaging enough to interact with — without causing socially undesirable consequences. Dykstra-Erickson (in this report) has outlined several principles for the design of such interfaces. Boyarski (in this report) addresses the educational implications of this shift in emphasis. Interfaces, it should be stressed, lie between users and technology — not to be confused with computer screens and other control surfaces. Interfaces are processes or interactive practices that are inherently immaterial or virtual. Thus, in an age of information, interactivity replaces materiality (see Krippendorff in this report).

3.3 Multi-sensory Involvement

Design should concern itself with all the senses in which its artifacts can arise. In the past, design has privileged the visual over virtually all other human senses. Witness the static depiction of exemplary designs in magazines and museum exhibitions. The design of human interfaces with computers has taught us not only that the visual must always be supplemented by other senses, touch and sound for example, but also that our traditional conceptions of design are woefully misdirected. For once, interfaces are dynamic. They require a coordination of seeing, touching, hearing, as well as pointing, clicking, dragging, and moving. The old semiotics with its classic distinction between indices, icons, and symbols according to their (fixed) meanings is being replaced by a dynamic conception developed in product semantics, among other approaches. Ginnow-Merkert (in this report) has explored the use in design of five human senses and in both directions. Virtual realities involve the whole body, particularly including the kinesthetic sense, largely because it is natural for people to rely on different sensory modalities for different kinds of information. In the immediate future, designers must overcome the impoverished equation of information with the visual, with text for example, and acknowledge the empirical fact that our involvement in human interfaces is strongest and most effective when it is multi-sensory.
3.4 The Need for Variability to Match Diversity

The variability of artifacts should match the diversity of their stakeholders' capabilities, needs, and conceptions. The engineering and ergonomic approaches to design seek to optimize efficiency of use, taking a typical or average user as their standard. This approach is fueled by the ideal of finding a single solution whose "techno-logic" is moreover familiar to a majority of users (see Henderson in this report). Several papers in this workshop concerned those marginalized by this approach to design: children, the aged, the less educated, and the physically disabled (see Koncelik in this report). Near universal access to information technology can be achieved only where artifacts are designed to be sufficiently multi-modal and variable, if not adaptable to different users' abilities and intentions. The five most important strategies for creating this variability are:

- **Product differentiation**, resulting from competition in pluralistic markets — can generate a multitude of products for sufficiently diverse groups of buyers. However, this marketing strategy bypasses and systematically marginalizes people that do not have the economic means to assert themselves.

- **Personalization** or customization — grants individual users a number of options among a usually predefined set of features with which a product can be equipped. Examples range from the colors of cars to the softwares that run on a particular computer. This is the simplest form of variation producers can provide.

- **Multi-pathing** — provides users with alternate paths to use an artifact. This strategy emerged in early self-teaching programs, informed numerous devices, from Hyper-Text to the World-Wide-Web, and now is central to Virtual Reality applications. Here, users can pursue their own goals and in their own time but in a world decided by others. Related to this response to diversity are multi-media systems that embody enough redundancy to be useable by people who may not be able to see, hear, or are in need of alternative forms of interactions. Multi-media systems may be fun, but the options they embody can be used to allow very different people to use it in their own way and to participate as citizens in an information society.

- **Reconfigurability** — provides users with tools for designing the very worlds they like to work with or play in. Individually configured systems need not be incompatible with one another. Thus, reconfigurable systems may not only afford different and changing user conceptions, but also enable users from different cultures to participate in global networks without even knowing the particular world others have designed for themselves.

- **Adaptability** is the ability of interfaces to automatically improve the fit between users' expectations and systems performance over their history of interaction. Adaptable systems learn to accommodate users' practices, particularly repetitive ones, and users need not to know much about the architecture of such systems, especially programming.

Information always affords multiple interpretations and the most outstanding characteristic of information technology is that it enables more and diverse people, even with previously considered disabilities, to communicate with one another, form communities on their own, and participate in the larger society. This amounts to enabling users of this technology to be new kinds of citizen of a new kind of society, each exhausting some of the available variability in their own terms. (The significance of variability for adaptation is well established in Ashby's (1956) Law of Requisite Variety).

3.5 Cooperation and Multi-disciplinarity

Artifacts should be designed to enable cooperation (see Galuszka and Dykstra-Erickson in this report), **honor diversity**, and **support conflict** (see Henderson in this report) rather than provide information. In the spirit of objectivism, Galuszka and Dykstra-Erickson point out that information fills the world and leads to overload (see also Entman in this report) and meaninglessness. But in the spirit of constructivism — and one should consider design to be fundamentally sympathetic to this philosophical perspective — it is the world that expands for cooperation to grow and filter out what is relevant to its participants.

The most natural way to design artifacts that enable cooperation, tolerate conflict, and prevent information overload is for development teams to engage in the very processes they wish to support. Designers have always worked with other experts, sometimes as artistic consultants, sometimes as the synthesizers of conflicting perspectives. The solution to multi-disciplinary problems is often cast in terms of finding a common language (see Dykstra-Erickson in this
Artifacts, especially of the information age, should be designed heterarchically not hierarchically. Herbert Simon (1969) wrote at the beginning of the computer age and from an engineering perspective. He theorized hierarchies of complexity, describing them with the mono-logic of a single discipline or viewing them from a single spectator’s (or God’s eye) perspective. He could not know fractals, catastrophe theory or chaos, nor experience the fact that hierarchical systems, that is, systems that are controlled from one center, or systems whose use required knowledge of a rigid formal (computer) language, tend not to survive in democratic, market oriented, and user-driven cultures. Information favors diversity. Networks are the archetypes of open and non-hierarchical (horizontal, heterarchical, parallel, and network-like) forms of social organization. And people work best when they realize themselves and in their own terms. Although designers might decry the loss of control that the old hierarchies gave them, heterarchy, chaos, synchronicity, inconsistency, diversity, and dialogue are the new virtues that drive the technology of the information age (see Krippendorff in this report) and provide far more fun. The success of concurrent engineering, collaborative software, the Internet, and many other contemporary information technologies stems from their heterarchical and essentially open systems architecture. (See also the conclusions of 6.1 in this report.)

3.8 Second-order Understanding

Human-centered design entails a second-order understanding, including the understanding by fellow human beings, which radically departs from our traditional objectivism. The kind of understanding that the natural sciences — physics, mechanics, computational logic — promote is mono-logical in the sense of striving to discover the (single) logic of the world, to construct a consistent system of explanations and laws, to find an accurate picture of THE uni-verse. This kind of understanding underlies Simon’s (1969) Sciences of the Artificial as well, as evident in his emphasis on hierarchy, logic, and rationality. This first-order understanding arose during the age of the Enlightenment and is now developing into a barrier to knowledgeably moving into an age of information.

Particularly, the shift from a traditional technological/functional/hierarchical approach to design to a human-centered one amounts to a call for a
The significance of the distinction between a first- and a second-order understanding lies in the fact that technical artifacts do not understand, whereas people can hardly act without it. They must therefore be treated differently. To be responsibly concerned with the human use of (information) technology, with how artifacts acquire meanings and uses for their users, requires concepts and empirical evidence that straddle naturalist accounts of a system, which are prototypically first-order in construction, and accounts of different users’ conceptions of such a system. Both must find their place in designers conceptions — without doing violence to either. When these rather different understandings are acknowledged and brought together in a designer’s mind, we do have an understanding that is not concerned with objects as such, with technical systems for example, but with the human understanding of technical systems, with the interfaces that users create as they enact this understanding, with how this understanding co-evolves in a society of other users, with the information that drives the use of technology, etc. In contrast to the mono-logical nature of first-order understanding, a second order understanding brings different kinds of understandings into interaction and renders this understanding dialogical in nature. Unlike a first-order understanding of a single world that all people are asked to agree on, a second-order understanding respects the diversity of different people’s worlds, the possibility of very different logics to coexist and interweave one another. Unlike first-order accounts of what things are, a second-order understanding is concerned with how people interactively construct, re-construct, or transform the kind of multi-versa in which other people can participate as well and enact their own understandings. Unlike the self-denying certainty with which first-order scientists account for their world (ontology), a second-order understanding acknowledges that any understanding of others’ understanding is but one of many ways of understanding (multiple epistemologies) and deserves no special privileges beyond that it works for their beholder, each being their own expert. This acknowledgment is an epistemological prerequisite for designers to contribute creatively and responsibly to an information society. Consequently, in a first-order understanding, “the age of information” remains largely incomprehensible and mysterious. With a second-order understanding we might come to grips with it.

3.9 The Delegation of Design

Design should continuously delegate itself. Information technology provides its users spaces to create their own worlds, to be designers in their own right (see Henderson and Krippendorff in this report). The design of such technologies therefore seems to undermine how designers had defined themselves in an industrial age. Simon (1969) identified design processes in many practical disciplines and effectively dissolved design into numerous disciplines while generalizing the process. This questions whether design can remain a profession. Supporting his generalizations, others have proposed that design should be regarded as a form of literacy and be part of general education, starting in kindergarten (see Burnette in this report). With this proliferation in progress, one must ask whether an age of information still needs professional designers? The answer might well lie in the new design principles outlined here. Clearly, communication is the most intelligent use of information technology, which means designing togetherness cooperatively. It takes place in the languaging of particular user cultures. Designing such technologies in the awareness of their possible uses means delegating to others some of the very design decisions that traditional designers were privileged to make alone. In an age of information, designers can do no better than staying ahead of those they work with, speaking a language that encourages others to participate in processes of design, and asserting compelling visions that can motivate others and reality will bear out.

In an age of information, design surely can’t continue what it used to be. It has to reinvent itself as a voice for a human-centered technology, and in fact is already doing so. The above design principles are a first
step to articulate what we as designers need to do to lead the information revolution and what we are asking funding agencies to encourage in whatever projects or research they support.

References


4.0 Preface

The design disciplines are currently in a state of flux. As recently as a decade ago, the boundaries of graphic design and industrial design were fairly tightly drawn. Graphic designers were involved primarily in designing printed communications, while industrial designers produced dimensional artifacts.

Designers today are involved in the development and design of virtual identities, web sites, strategic plans, new products and their interactions, software, wearable computers, digital libraries, and interactive exhibitions. The old monikers of graphic and industrial design aren't descriptive of the new fields of practice and research that are being explored today. These disciplines in fact have come to realize that they do not own the word 'design.' The activity of design, as described by Simon (1969), is being practiced by a host of disciplines that include engineering, computer science, information systems, and business. We see titles such as software design, engineering design, human-computer interaction design, and systems design, to name a few. If design is pervasive, who, then, is a designer and how is s/he educated (Strong's presentation, not in this report)?

A unique opportunity presents itself to the fields of graphic and industrial design. This opportunity suggests a partnering, not just with each other, but with the technological, humanistic, and business fields in the development of new products - real and virtual. These products touch the everyday lives of people, young and old, in school and at work, at play and at rest. It will take an attitude of openness, cooperation, and exploration on the part of educators, administrators, students, professional designers, company executives, and funding agencies - with new and continuing education as the goal. New methods of working together will evolve, as will evaluation and discussion of such practices.

We must consider a change in the way we conceive of design education. While change may not be easy, it is clear that some changes are necessary. Some observers even point to drastic changes. This demands that we review - literally, re-look at - what we do in design education from different points of view. Definitive answers are yet to emerge, but over the two days of
discussion at the workshop, consensus was reached in
describing some of the major issues surrounding design
education for the future. The recommendations are not
exclusive of each other. In fact, it should be noted that
they overlap each other and should be considered
together.

While this report addresses design education, some
may regard this as pertaining solely to graphic and
industrial design programs. Simply substitute your
department's name in place of graphic or industrial
design, and read on. These issues are germane to all
those programs that are concerned with human beings
and their interaction with new technological products
and environments.

4.1 Educational Structures

Here are several scenarios describing education in
the future: not all learning will take place in schools;
courses will be of drastically different lengths; learning
will not end with a diploma; there will be less structured
and less codified ways to deliver education; there will be
unique cooperation between academia and industry
with new and continuing education as the goal. The
design of life-long learning is the issue at hand (Mayo's
presentation, not in this report).

We are currently constrained by an antiquated
educational structure, one built on courses offered over
semesters or quarters; on autonomous departments; and
an emphasis on individual (faculty or student)
achievements. As a result, barriers exist to building
courses outside of existing structures, to team-teaching
across departments, to supporting a range of teaching
styles for a range of topics, and to partnering with
industry in the pursuit of collaborative projects. This
problem is not unique to design programs, but is shared
across departments on campuses around the country.
Those faculty that have successfully overcome these
barriers point to enlightened participants from within
academia, design firms, and industry - enlightened in
that they see the value of collaboration and the
potential for new ways of teaching (see Roth in this
report). They promote and reward cross-disciplinary
efforts.

We can no longer continue to subscribe to
outdated boundaries between design disciplines.
Instead, we should either cross these boundaries or
transcend them (see Krippendorff in this report). This
suggests two concurrent paths for design education:

- to explore collaborative methods that enable
designers from different disciplines to apply
themselves to new information-related problems
with new information technologies, and
- to build new educational programs for those who
do not fit within current programmatic boundaries.

The challenge for design education is this: how
flexible can our educational structures be in order to
support, even nurture, new ways of teaching tomorrow's
designers?

Recommendation One: Firstly, when sponsoring
project courses at universities and colleges, government
and industry should specify that the work be carried out
by integrated teams representing several disciplines,
each relevant to the task at hand and able to address
the many issues related to product development, design
planning, production and implementation. This
requirement will send a strong signal to academia and
encourage new structures and new approaches to
collaborative design. Secondly, NSF and NEA should
work closely with the national professional design
organizations - such as the American Institute of Graphic
Arts (AIGA), the Industrial Design Society of America
(IDA), and the American Center for Design (ACD) - and
lead the way in exploring new thinking about design
education. Their findings should be shared with design
and other relevant academic programs around the
country in an effort to put into practice what is
preached.

4.2 Interdisciplinary Design

While there may be general agreement that our
students need to have interdisciplinary design
experiences, we need more success stories that one can
point to as models. Typical design projects have
designers working with other designers, or a designer
interacting with a client, but few projects actually
involve students from several disciplines working
together to solve a problem. An important distinction
should be made at this point between the terms
multidisciplinary - a collection of disciplines brought
together to solve a problem - and interdisciplinary - a
collection of disciplines on a team with a shared
commitment to solving a problem (Buchanan and Vogel,
1994). It may be relatively easy to assemble a
multidisciplinary team, but to ask the participants to
work constructively and efficiently together over a
period of time demands an interdisciplinary attitude.
This suggests integrating approaches from other
disciplines, allowing for “multiple sightings” on a problem (Strickland’s presentation, not in this report). It further suggests designing a system that allows for all to design, with some addressing meta-design issues, while others address the details (J. Henderson’s presentation, not in this report and 6.5 in this report).

The challenge before us is to foster interdisciplinary design projects in various departments across a typically diverse campus. It takes a commitment from key faculty in these departments to make it happen. It also takes an attitude of openness and exploration on the part of departmental administrators to see the value in these kinds of projects and to encourage them among their faculty and students. Providing incentives for faculty to find new arenas for collaboration should be the job of department heads, deans, and provosts. It will be in these new arenas that innovative thinking and activities will take place - innovations that spawn innovations (Rheinfrank’s presentation, not in this report).

Recommendation Two: Governmental agencies, like NSF, and industry should play an important role by sponsoring major interdisciplinary projects focused on designing collaborative design environments, with real and virtual aspects. These environments would link researchers - students, faculty, and industry representatives - as they work on developing new collaborative technologies. Associated with this work should be research into the processes and methods employed for such collaboration, as well as the environment for collaboration itself. An understanding of the unique and tangible contributions from the various disciplines will go far in promoting efficient and productive collaboration. In short, a fuller understanding and appreciation for what collaboration across disciplines means, and what it takes to achieve this, is at the heart of this project.

4.3 Human-centered Attitude

Within some design programs around the country, a shift has taken place from a focus on formal issues (form-giving and aesthetics) to a focus on the human beings that are affected by designed artifacts. This attitude - and it is an attitudinal shift - takes into account the human factors of cognition, behavior, even social and cultural influences (see Roth in this report). Krippendorff’s new design principles are an articulation of this shift that has relevance for any discipline involved in new product development (see 3 in this report). It is a shift that recognizes the fact that without primary consideration for the people using the artifacts we design, and the context for their use, - in short, the entire experience of use - we relegate design to a self-serving activity. In fact, this concern for the human use of products and systems is what distinguishes design (graphic and product) from engineering and computer science. Designers add value to interdisciplinary work precisely because of this ability to consider users. Equally important, this shift allows design to share its approach to human-centered design with other disciplines also involved in the search for ways to keep the audience/user/person in mind throughout the development process.

This human-centered approach is undergoing an evolution from user-centered design (considering the audience) in the 80s, to participatory design (involving the audience) in the 90s, to design partnerships (involving the audience and client) in the first decade of the new century (Sanders’ presentation, not in this report).

Recommendation Three: Courses that inform designers of human behavior (i.e., cognition, social/cultural factors, people and organizations, people and technology, evaluation methodologies) should become part of the design curriculum. These should be taught with the goal of applying this knowledge to integrated product development. Within existing design courses, issues of product semantics, communication and interaction, and data visualization (information design) should be strengthened.

4.4 Reflection on Practice / Building a Design Literature

Understanding what we do as designers is a never-ending research topic that should be promoted and explored in every way possible. It suggests that serious reflection on these activities (Schon, 1983) and documenting them is necessary to building a body of literature that is direly needed by the design (and related) disciplines. Such a body of literature can contribute to a healthy discourse that unites the design communities. We should explore various means to document what we do and not be limited to writing formal papers, all the while keeping an eye towards ready dissemination to as wide and diverse an audience as possible.

Recommendation Four: At the conclusion of a major project, undergraduate design students should be encouraged to provide reports that document their design process. This task of reflection, collection,
writing, and editing demands an objective point of view in pulling together a report that is informative to and readable by any interested party (see Boyarski in this report). Graduate students should contribute with a written thesis that attempts to broaden the current thinking and knowledge base of the discipline. Finally, each year, faculty should agree to write one paper, give one presentation, or participate in a public discussion that contributes to building this knowledge base about design.

4.5 Design Education Tomorrow

As mentioned at the beginning of this section, there are many activities and disciplines that are considered design disciplines, in light of Simon's broad definition of design. In the foreseeable future, there will continue to be formal design education for tomorrow's designers. Undergraduate programs will still focus on professional preparation. Master's programs, currently the terminal degree, will also be involved in professional preparation, but with a research component that distinguishes it from undergraduate work. Graduate programs may be the critical ones for the future, as the task of redesigning design is at the core of graduate work (see Krippendorff in this report). Excellence in scholarship and innovation should be the twin goals we aim for.

Recommendation Five: Disseminate current literature about design education to those within and beyond design programs. Then, convene an annual Design Education symposium devoted solely to the issue of educating the new designer, initially as defined by Simon. Content will focus on new thinking, new courses, research projects, and other activities that inform the education of this new breed of designer. This symposium, funded by government and industry, may move from campus to campus, but be guided by the same set of goals and objectives.

4.6 Early and Late Learning of Design

Two other educational needs must be mentioned: 1) learning design thinking as a basic skill on the elementary and secondary levels; and 2) continuing education for a population that may be growing older in years, but not waning in energy, curiosity, and the desire to keep learning (see Koncelik in this report). In both cases, we must start with an understanding of learning - not just teaching; this is critical before we get too caught up with new technologies. Certainly, we need to explore augmented and distance learning, but we should do so with wisdom and care for those we are teaching. These explorations should take place in relevant departments across campus, and not only the Education department.

Recommendation Six: NSF should fund projects that explore distance learning coupled with interactive technologies. The implications for content development, organization, and visualization, as well as technical delivery - divergent applications on convergent technologies as a goal (Purcell's presentation, not in this report) - are aspects that need serious consideration. Equally important are implications of distance learning on learning itself, the quality of the experience, the resulting work, and student mentorship. Clearly, this is multi- and inter-disciplinary work with representation needed from the fields of psychology, education, writing, design, film, and computer science, to name but a few key areas.

4.7 Summary

New participants, new initiatives, and new thinking are needed if the design disciplines are going to be contributors to the larger picture of design in the Information Age. Change is imperative on three fronts. First, change is necessary in academia, not only within design education, but with programs that are potential partners in collaborative projects and research. Second, change in thinking is needed with companies and institutions that may stand to gain from partnerships with academia in the form of sponsored projects or research. Third, change is imperative with funding agencies that fail to consider design programs at universities and colleges as recipients of major grants. There is serious ongoing work in various design programs around the country that can greatly benefit the general theme of product development in the areas of smart products, software design, and information design. Put another way, the fruits of design's labor can be found in everyday products, for all kinds of people, doing a variety of tasks.

The discipline of design has much to offer - principles, theory, methodology, and a unique way of seeing the world and approaching problems. In collaboration with other disciplines, much more can happen to inform the future of this highly technological age, sorely in need of humanizing and clarifying.

Each of the areas mentioned in this report lists the need for further study, reflection, and documentation.
These activities are dependent on strong support from government agencies, like NSF, from industry, and from academic administrators. The recommendations that follow each section all cluster around a few key themes: human-centered design, collaborative environments (real and virtual), interdisciplinary team work, reflection on and documentation of the design process, and the new boundaries of design. What is common to the recommendations is the need for support, in the form of equipment, electronic/digital links, and financial support for faculty and students. Visionary leaders within our schools, the government, design firms, and companies can make an enormous difference. Are we all ready to take the next step?

References


Additional Publications


GDEA (Graphic Design Education Association) Conference on Design Education, summer 1995: white papers are currently in preparation.

5.0 Preface

Part of this workshop's assignment was to propose a research agenda for design in the next century, particularly, to achieve consensus on the goals outlined in 1.1 NSF on Design in this report. These goals call for the design of new kinds of technologies, whose beginnings we are witnessing right now, technologies that have the capability of providing ordinary citizens with unprecedented access to information, enable people to communicate with one another in spaces previously unimaginable, and transform the way we organize ourselves in a new kind of society and in pursuit of new social values, most of which as of now unclear to us.

Consensus on a research agenda of this magnitude is difficult to achieve, largely because we may have dreams but no data on how life in an information-rich society will look. However, this uncertainty is constitutive of design and therefore no threat to us. It lingers behind all recommendations in this report. So, without claiming complete consensus, we are outlining below several major research initiatives that we consider worthy and timely to pursue and therefore recommend their generous funding and support. The knowledge these research initiatives promise to generate is likely to open opportunities, otherwise missed, for the new information society to be more friendly to all of us.

Any of the projects we suggest might involve several phases:

- Preparatory research (to frame a challenge),
- Seed grants (to stimulate effective proposals),
- Implementation grants (to carry out a project),
- Integration workshops (to compare and assimilate results),
- Major collaborations (to put a whole system together).

5.1 A Research Paradigm for Design

The history of scientific research is still very much rooted in the history of the natural sciences. These sciences are indebted to the Cartesian assumption that there is a nature apart from us to be explored for what it objectively is. Within this research paradigm, scientific research means re-search, that is, searching and
searching again, using more data to make better predictions, trying to discover all the laws that operate outside and independent of us, always under the assumption that the logic of the past will continue in the future.

This objectivist epistemology, which appealed to designers during the industrial revolution with its preoccupation with products, is now becoming increasingly incompatible with design in the coming age of information. "The natural sciences," Simon (1969:58-59) pointed out a while ago, "are concerned with how things are.... Design, on the other hand, is concerned with how things ought to be, with devising artifacts to attain goals. We might question whether the forms of reasoning that are appropriate to natural sciences are suitable also for design." Moreover, whereas researchers in the natural sciences construct their universe as a continuation of an observed past, designers are intent to change it — regardless of historical precedents. In fact, design is always measured by the intrinsic value it delivers to society as a whole. Designers, therefore, are not afraid to violate stated constraints, if this is at all possible and useful, and act to assure that undesirable constraints will have no future. Our well-known inability to predict technological developments (see 2 in this report) is living proof that the kind of lawfulness scientific research is well equipped to describe is hopelessly inadequate in the artificial world, a world that designers always are in the process of reconstructing.

The kernel of the answer to the question NSF asked us to consider, what can the Federal Government do to support relevant research in design, lies in the very way it was presented to us. Gary Strong (in 1.1 of this report) asked three questions, answered two, and left us to explore the third: Where are we? Where do we want to be? and What do we need to get there? These are the very research questions designers pose and answer all the time, but scientific research and design research express fundamentally different ways of approaching the world.

During the workshop, there was consensus on the centrality of this paradigm for design and the key role it plays in generating knowledge that would make designers a stronger partner in any development effort. A search methodology should enable us to
- systematically generate compelling images of realistically achievable futures,
- explore how existing constraints can be weakened, bypassed, or overcome, for example by reconceptualizing presently assumed givens,
- create and explore alternative paths to link present resources to these futures, and
- propose heuristics to balance the costs of proceeding along these paths with the future benefits that are likely to emerge from each. The latter component is reasonably well understood as rational decision theory (Simon, 1969). The former are still very much embodied in designers' intuition.

Our first recommendation is, therefore, to support the systematic articulation and elaboration of a research paradigm for design. Part of this recommendation could be conceived of as a continuation of Herbert Simon's (1969) project. Knowledge of how to move into a principally unknowable future is what justifies design and all kinds of development efforts, including public policy making. It offers a rational basis for allocating resources to technological developments and grounds arguable strategies for steering the information revolution into a desirable direction. What is needed are systematic investigations into currently used design strategies and their formalizations into well defined design methodologies. We believe this neglected research paradigm would benefit not just design but could bring the methodologies from several intervention oriented efforts together. The support requested may start with funding conferences and workshops on the subject as well as underwriting specialized projects. Minimally, it is suggested that all grants secured for the development of information-human-centered technologies be required to reflect on their often situation-specific justifications and thus contribute at least case studies to a future research paradigm for design.

5.2 A Second-order Science of the Artificial

In his The Sciences of the Artificial, Simon (1969) defines their domain as the adaptation of the natural world to human goals and outlines some of their common ingredients:
- a deontic logic (of "should," not "is"),
- the concern for search strategies for achieving ends,
- a rational decision theory (utility theory), and
- optimizing techniques and satisficing heuristics.

While these ideas caused a major shift from accounting for facts to creating them, his notions are still rooted in the Enlightenment ideals of human mastery over nature. This excludes the possibility of questioning the consequences of holding this and other
world views. The notion of a singular rationality also fails to acknowledge that this is but one of many equally valid ways of understanding the artifacts of this world. Even where Simon writes of people, by addressing issues of management, for example, he does so in terms of hierarchies — a top-down mono-logic — and in terms of rational choices which can no longer explain much of what is happening in an information-rich and densely networked society (see 3.6 in this report). What is needed, therefore, is to transform his first-order ideals into a second-order science for human-centered design.

Human-centeredness acknowledges human beings as the source and the target of all artifacts, with technology merely connecting the two in an arguable and (literally) constructive way. The knowledge needed to design human-computer interfaces may serve as a prototypical example of the kind of understanding needed to design information systems. As already noted (3.8 in this report), an interface is not merely a neat display of text and images. Many computer scientists, citing Tufte’s (1990) work as an example, naively believe this is all that designers can contribute. However, designers’ expertise would be wasted if forced into this first-order understanding. An interface, to be sure, joins the causal networks of a technical system with the understanding users have of it into a dynamic system. For human agents, interactive participation is voluntary, self-motivated, and based in their understanding. Technical systems, by contrast, do not understand anything, are fueled by energy, not motivation, and have no agency nor options to choose from. Thus, an interface is a hybrid of the two, a cybernetic organism, a cyborg, in which human users enact their understanding and, in order for an interface to persist over time, the participating technology must afford that understanding. In fact, to afford human understanding is the only criterion technology must satisfy. Efficiency criteria, for example, are subsumed by an understanding of what something is designed to be, its purposes, its meanings for a particular group of users.

In order to design an interface, it is therefore indispensable to know the multiplicity of conceptions potential users bring into it and how each of these conceptions can be afforded by the causal network that artifact designers ultimately specify. As already mentioned, this knowledge links two potentially different kinds of understandings, the designer’s (first-order) understanding of an artifact and the designer’s (second-order) understanding of the user’s understanding of the artifact. These two understandings are necessarily different from each other, none a priori superior to the other. We argued that this second-order understanding is radically different from the ordinary understanding of artifacts “in themselves.” For the engineers of technical systems, a first-order science is adequate because it provides knowledge of systems that do not understand the way engineers do. For the designers of human interfaces, by contrast, detailed understanding of users' understanding is indispensable, and this is what a second-order science of the artificial will have to provide systematically and reliably.

A second-order science replaces the ontological question of “what something is” by the dialogical question of “whose actions bring it forth,” or “who is constructing it” that way and why. Such questions are dialogical because the only way to answer them is by either observing the interactions within an ongoing interface or by engaging in dialogue with whoever has a stake in such interactions. A second-order science of the artificial respects human differences in understanding, including the understanding that observers, designers, engineers, bring to an artifact — without privileging any one on other than practical grounds. All stakeholders in a particular technology enact their own understanding and collectively cause an artifact to become how it is being used.

To argue the uniqueness of this second-order science, consider two related intellectual projects: Cognitive Science seeks to find general rules for how people think, solve problems, process information, and act intelligently — but always in a world that is presumed same for everyone and from which performance criteria can therefore be derived. By contrast, a second-order science would seek to find out how particular user groups or cultures have their particular way of conceptualizing their practices and go on in their world. Generalizations always refer to majorities and marginalize deviants, the disabled on the one extreme and the specially gifted on the other. Design that drew on scientific generalizations was in vogue in the 60’s international style, which was not only elitist but also insensitive to cultural differences. In an information society this is manifestly undesirable. The other example is Artificial Intelligence (AI). AI attempts to develop computational models of human intelligence. This effort has spawned much of the information revolution we are now experiencing but has less and less to say about human beings. One fundamental reason for this increasing inability is that AI seeks to create algorithms that are by definition disembodied, i.e. can be implemented on any computer with appropriate capacity, and must therefore ignore the kind of background understanding humans bring into human intelligence, intuition for example. The other reason is that algorithms are determinate and can not possibly
model human agency, the ability to create spaces, move in them freely, and find places to comfortably occupy. AI has been remarkably successful for the wrong reason. It claims to model human intelligence, but has at best extended it (Winograd and Flores, 1986). Claims to understand human intelligence in terms of algorithm can be convincing but not when this understanding is to understand itself or any other ways of understanding — which is central to design and in a society in which more people than ever are connected and interact intelligently with one another and in wholly novel ways.

Among the intellectual efforts that could make contributions to the formulation of a second-order science are ethnography in anthropology (see Boyarski in this report), hermeneutics of text interpretation, second-order cybernetics, constructivist epistemology, constructionism in psychology, narrative theory and other language based analyses of metaphors, metonymies, and user conceptual models, conversation theory or dialogue, and self-reflexive approaches in sociology.

Developing a second-order science for design is of increasing importance in a society, such as ours, whose information infrastructure is changing at unprecedented rates with the real possibility of technologically disabling an increasing number of people to participate in the intellectual and political life it could offer. If a future society is to be inclusive of a diversity of our citizenry, then support of the development of a second-order science of the artificial is one important step in creating human-centered technologies.

5.3 A Semantics for Interfacing with Artifacts

The turn towards semantics is one of the more exciting recent developments in design. A semantics for interfacing with artifacts offers designers a technical discourse that

• grounds design in an empirical domain, not occupied by other disciplines,
• enables clear formulations of design problems in a human-centered way, and
• facilitates negotiations of design solutions — from a position of both rigor and imagination — with experts (stakeholders) from other areas of product/systems development. Moreover, it
• provides a vocabulary in which terms empirical research can generate the knowledge necessary to design all kinds of human interfaces with technology — more responsibly than previously possible.

By definition, product semantics seeks to understand users’ understanding of their practices of interfacing with the objects of their world and provides strategies for designing artifacts that can afford or supportively intervene in that understanding (Krippendorff, 1990). This two-part definition entails

• a second-order science by which we can systematically explore and analyze the diverse ways people interact with the objects in their surroundings and through them with each other, and
• a practical methodology that aids the process of designing artifacts and provides us with compelling justifications for its results.

The word “product” should be interpreted broadly to include all kinds of artifacts from simple hand tools, to corporate product languages and complex information networks — all of which require that humans interface with them, which is the primary target of human-centered design considerations.

Key to product semantics is its concept of meaning — not as an entity that could be attached to things, conveyed by vehicles, contained in texts, intended by authors, or specified by the designers of an artifact, but — as the many ways users can embed an artifact into the context of their understanding (of their world, including themselves, their surroundings, their purposes, and of other human beings). (See 3.1 in this report for the axiomatic nature of meaning in design). Meaning is the human-centered concept par excellence.

All humans, it is supposed, enact their own understanding, move accordingly from one sense to another, and thereby bring forth interfaces with a world they cannot know apart from their own interacting with it, a world that designers attempt to alter. Technology, it would follow, has to be designed so as to afford the practices that arise out of its users’ understanding or enable their understanding to develop while being afforded. The semantic turn in design, concurrent to similar turns in other disciplines, is most important in an information society, of which we know very little except that people will be able to access far more information, interact with far more people and, most importantly, through far more complex artifacts than ever before. Product semantics is an approach to design that addresses the interfaces by which people can make use of systems whose complexity would otherwise exceed individual comprehension. Its aim is to make all interactions with artifacts as natural as talking,
gesturing, or using small hand tools and as involving as playing games. Locating artifacts in the context of users’ understanding makes product semantics sensitive to individual and cultural differences that previous approaches to design largely ignored.

The research and development agenda of product semantics includes:

- Developing **a dynamic and interactive semantics**, a theory of meaning and sense that takes off from experiences with the design of human interfaces with computers. The semiotics of Charles S. Peirce, Charles Morris, and Bertrand Russell, to name but a few, including recent French incarnations of semiotics, are mainly concerned with representations, explain at best why icons work, but are otherwise totally unsuited to the kind of dynamic interfaces we are developing right now — with only the beginning of systematic knowledge available.

- Developing **a stakeholder theory** for information technology (see 3.0 in this report). The industrial age defined users as the **end-user** of industrial products, limiting design concerns to the interests of industry in the most typical “consumer.” In an information age, this user conception is no longer adequate. Information technology caters to a great diversity of users (ideally all, the so-called disabled especially included), not merely to the most profitable classes. It has the capacity of networking all people who have a stake in this new technology, without flooding a mass market with identical products. Its essence is interactivity, mutuality, virtuality, active engagement, emergence, not passive satisfaction (aesthetics) with impersonal artifacts. The emerging conceptions of how diverse people claim their stake and actively participate in the use if not the design of technology requires further attention. Stakeholder theory overcomes traditional user conceptions and sheds new light on the political context in which design must increasingly operate.

- Sharpening key distinctions and **elaborating the vocabulary** of product semantics: meanings, sense, affordances, user conceptual models, metaphors, metonymies, self-evidence, intrinsic versus extrinsic motivations, signifiers for states, places, pathways, processes, navigational tools, creative agents, passages to different worlds, communication across worlds not shared, etc. From the perspective of a second-order science, these concepts aim to describe the multiple roles artifacts can play in the lives of individuals, work groups, cultures, and institutions. From the perspective of a practical methodology, these concepts attempt to enable designers to propose artifacts that have the potential of working their way into the worlds of their stakeholders and survive different user conceptual models, languaging, etc., including interactions with other artifacts. Concepts have been developed in four contexts: of use (actual interfaces), of language (how we talk of artifacts), of genesis (their design, implementation, and maintenance), and of ecology (interaction among different species of artifacts). This vocabulary needs further refinements and extensions.

- Formulating practical **design methods** that iteratively build diverse stakeholders’ understandings into the design process has been a major concern of product semantics from its beginnings. This can proceed either directly, by participation, or indirectly, after researching the possible worlds of stakeholders into which an artifact must be designed to enter. (For an example see Butter in this report). Design would benefit greatly from generalizing some of these design strategies.

- Improving ways of analyzing and measuring **meanings** and associated concepts that enable systematic explorations of semantical phenomena, an orderly accumulation of research findings, and arguable evaluations of designs. When design concepts are not merely empirically grounded but also measurable, designers’ claims can be made far more compelling. Past design arguments in terms of functionality, utility, material appropriateness, coherence, and aesthetic appeal, are no longer compelling when applied to the kind of intelligence an information society produces. From the perspective of a second-order science for design, measurement challenges traditional assumptions of measurement theory.

- Organizing **conferences or workshops** on product semantics as a way of providing a clearer empirical grounding for designers. To date, such conferences have been hosted by artistically oriented institutions, nationally as well as internationally, and were motivated more by the newness of semantical concerns than by a commitment to advance the field.

- Publishing research results, books on the new semantics, and exemplary results of applying semantical considerations to the design of products
and systems are an important means of creating texts for workshops on semantics and courses in design, for suggesting guidelines for industry, and, above all, for inviting scientists willing to branch out and designers eager to collaborate in a development that clearly is the brain child of an emerging information society.

Next to a research paradigm for design and a second-order science of the artificial, a semantics (for interfacing with artifacts) provides the third leg on which a human-centered technology will be able to stand firmly in the future. The semantic turn is creating a new kind of awareness of the human role in the use and development of technology and encourages a new kind of partnership between design and other, so-called, hard disciplines. Product semantics is a project that deserves generous funding and support.

5.4 Multi-disciplinarity

The need to work in multidisciplinary teams was identified as a common requirement for success. Systems that communicate information, search for or process information, are too complex for a single discipline. But an even more important challenge is that such systems may have few precedents, without the classical conceptions of mechanisms or organisms. Information systems of this kind essentially reside between disciplines and therefore require inter-disciplinary cooperation. In 3.5 we suggested that design should enable cooperation, honor diversity, and support conflict (see also Henderson in this report). In 4.0 we identified the need for good models, and explicit working knowledge, of how multi-disciplinary teams accomplish their tasks. Smith et al. (in this report) explore the role of designers as team members in the development of interfaces for a national aviation system and show its difficulties as well as its rewards. Galuszka and Dykstra-Erickson (in this report) go so far as to equate design with collaboration. Metros (in this report) proposes a model for funding collaborations in design. Thus, there is much awareness of the urgency but little hard knowledge of how to institute inter-disciplinary collaboration knowledgeably, precisely because human nature is as heavily involved in the process as is technology.

We recommend that a multi-pronged research effort be launched to understand and technologically support multi- or inter-disciplinary collaboration on design. Among the proposals suggested are:

- **Networking design centers** at major universities that can draw on different knowledge bases around a specific design problem. Networking for its own sake may not be the answer. To be viable, such networks must be motivated or produce tangible rewards that make collaboration more attractive than working alone. Once used successfully, it is likely that such centers find more applications and develop a life of their own. In 6.4 (in this report) we propose, firstly, a virtual design institute capable of pursuing design projects that would involve a networked group of designers and, secondly, a virtual design educational initiative that would network design schools and enrich their educational resources.

- **Design of collaborative software** for dispersed groups of experts to work together on a particular design project. To be clear, there already is collaborative software available, in the form of concurrent engineering for example, or in various business applications, most of which concern very clearly circumscribed activities. This would make them applicable only to the most obvious and repetitive design problems. Collaborative software in design must be applicable to its own process, be developed in cooperation and thus become both the target of the search and the means to achieve a result.

- **Design of collaborative procedures** that can be embodied in human practices. Collaboration is essentially human. It may be supported but cannot be replaced by technology. We need to search for constructive ways of languaging, for roles that people might play as members of a creative team, and for a healthy balance between private and public spaces that would encourage collaboration to arise. Research into such collaborative procedures would center less on technology, at least in the beginning, than on what the collaborators need to do to foster co-creative processes that produce successful artifacts. As such collaborative design procedures become better understood, the members of such reflexive teams will naturally draw technologies into the process.

- **Techniques for attracting stakeholders** into a design process. When one speaks of human-centered design, it is essential to draw as many stakeholders as possible, not just end-users, into the process. Most current techniques proceed from a system designer's or producer's definition of what the intended user groups for the system are, invite representatives of such groups into focus groups or
other data generating settings, without giving them any say in the process of design. To take the claim of human-centeredness seriously, which is imperative in an information society, techniques that invite stakeholders to assert their stakes and participate as partners in a design projects are urgently needed to make the future acceptance of a design more likely.

- As an extension of the above, we have also been exploring the need to find ways of enabling a future kind of citizenship, designing the kind of information technologically that make it possible and appealing for people to participate creatively in the proceedings of their government — not merely as voters or as bears of certain attitudes on an agenda set by pollsters or politicians. The rapid growth of Internet-like systems fuels the hope that a new, more responsive, and more engaged kind of citizenship is in the making. Unfortunately, the Internet does no more than provide information from point to point without authorial responsibility — which is essential to democratic forms of government. Citizenship too might be conceptualized as a collaborative technology, one that allows many voices to have an impact on the creation of national agendas, for example.

Multi- and inter-disciplinarity has many faces. Ways of better utilizing the tremendous resources people with diverse backgrounds and competencies can bring to a common problem are important. Systematic searches and developments for cooperative technologies are recommended for funding support.

5.5 Information

We speak of information as if it were an entity that could be passed from one place to another much like physical objects can. This illusion is supported by the experience that we obtain information while reading texts or examining images on a computer screens and therefore easily confuse information with them. Claude Shannon’s (1949) information theory sought to overcome this naive notion by providing statistical formulations of how measures of different varieties relate to each other, out of which came theories of coding and solutions to the problem of accurately reproducing messages at distant places. This feat tied his theory closely to what is called the technical problem of communication. But the transmission of a measurable variety is altogether different from the problem of understanding how humans receive, read, understand, and act on this knowledge — which is not what information theory addresses. Talking confusedly of information, of the information super highway, or of an information society is fine when this talk does not much matter but it may be precarious when expensive development efforts are justified in such terms.

In order to design the information systems of the future it is not enough to talk metaphorically, for example to speak of information architecture, to think of messages as conveying information, or to believe that a text, when reproduced elsewhere, could contain the very information its author intended. The word “information” that highlights the exciting new systems we are developing is at best ambiguous and at worst deviously misleading our understanding of why we are developing this technology. This is not a good starting point for designing what may structure our future.

What is needed is a concerted effort to understand what information technologies do provide us as their users, as their beneficiaries, as well as their designers and proceed from there to the question of what these technologies should mean for us. We can readily agree on some starting points for this exploration:

- Information does not exist without a community of users (readers, observers, including those who undertake to measure its quantity). Information arises in the process of cognizing sensory experiences, reading a text for example. Information must, first of all, make sense, and this sense is undeniably someone’s sense, not a text’s, but also of someone who is a member of a particular culture. This fact does not make information entirely subjective, however.

- Information is always relative to what is already known. Something repeated is emphasis, perhaps, or an insurance against unreliability or forgetting, but not information. Receivers of information always start with knowing something and end up knowing something else and this change need not always be an increase.

- There is nothing inside, contained in, or carried by images, texts, and ultimately pixels. What communicators can do at their best is to anticipate that their actual “doings” afford a desirable range of senses, meanings, interpretations, answers, ..., or information. Designers are not exempt from this.

- Every text, every screen, every design affords many interpretations, many meanings, different kinds of information, not one. It is naive to think that the design of a common language could solve all problems of communication. In fact, a common language, especially when designed into an
information system, is likely to fail that system if its use depends on the cooperation of many people (see 3.4 and 3.6 in this report).

- **Transmission of information works** not only because a system, as a channel of communication, is resistant to noise, but because its users live in similar consensual domains, or have co-evolved within a particular culture in which “transmission” makes sense. In fact, it is user cultures that can make particular systems into information systems. A technology either affords such a conception or it cannot.

We have to make a concerted effort to overcome the blurred but currently prevalent ideas of information and replace them with concepts that can get us into a desirable future. **Research is badly needed to reconceptualize information interactively, dialogically, realistically, and to develop compelling theories of how information technology relates to people.** During the workshop, heated debates between participants from different ideological persuasions testified to both the rhetorical significance of research in this area and our current increasingly troubling state of ignorance.

### 5.6 Coordination Theory

The guiding ideas of current information technological developments — to make the same kind of information universally accessible — clearly stem from our Enlightenment past. This era celebrated knowledge for its own sake, believed in the inherent goodness of standardized education, created industries of mass production encouraging us to think of exchangeable goods, now including information, as what people need and consume for their own good. It also entailed the belief that we could create a rational society whose only problems result from miscommunication, lack of information, uneducation, and irrational and deviant thought processes. Finally, it promoted the idea of individualism within an environment to be exploited for the benefit of humans and humans alone. It is remarkable how these ideas continue in the face of a totally different world.

Notwithstanding the excitement the new information technologies have created for many people who in turn strive to further their development, building these possibly obsolete ideals into future technology may well be misguided. In pursuing ideas of universal access to information we might be looking at only one part instead of the larger picture. Maybe we should not ask what we as individuals cognitively gain from being connected to information technologies, from the Internet to digital libraries, but what these new technologies do for us collectively, from how communities alter their ways of working together (or against each other), to the kind of social/political structures they support, to the kind of day-to-day operations they afford.

One still too sweeping answer to these questions is **coordination** (see DeYoung’s presentation, not in this report). As individuals, we might believe we use the telephone to exchange information and this is real to us. But the information we get enables us to arrange meetings, to close deals, to reach consensus on courses of action, to maintain interpersonal relationships, to get a report, including this one. The telephone, public television, the Internet, digital libraries, electronic airline ticketing, stock market management systems, all of them have in common that they intervene and enable certain kinds of coordination of people, investments, transactions, research, production, transportation, ticketing, etc. All information technologies, one might hypothesize with considerable conceptual benefits, are embedded in or hosted by processes of coordination and are largely paid for by the organizational benefits derived from the change in coordination they induce. Information technologies seem to reorganize their hosts.

**This is not just true for business.** The very idea of citizenship involves mechanisms for participation in government, from voting to protesting to organizing political campaigns, whether to get a politician elected or a legislative bill defeated. Looking at the “information” a system provides to citizens, however important this might seem individually, may well be beside the point, or is at most only a part of the processes of coordination into which information enters. Designing systems with the aim of providing more information might just be beside the point as well.

We have to make a concerted effort to understand the new technologies in the social context of the coordination they provide, seeing them as hybrid systems composed of institutional structures, that are constituted in the actions of individuals coordinating their activities relative to each other, and technological infrastructures, that facilitate, or inhibit certain kinds of coordinations. Many coordinations we are engaged in are latent and unattended for lack of adequate concepts. Other coordinations are understood as different kinds of phenomena, for example, cherishing information in and of itself, as an entity without attending to what it does. As of now, we have no organization theory that could embrace in a second-
order way the different worlds that information technologies now begin to coordinate. Looking at access and connections is again merely a partial view. We need to develop a comprehensive theory of coordination that helps us to understand how the new technologies constitute themselves in society and what they do to the way people live through them. With the help of a theory of coordination, designers might be better able to direct their attention to what really matters (as opposed to being sidetracked by outdated efficiency criteria) and policy makers might direct our scarce resources to the development of socially more responsible technologies (as opposed to jumping on the bandwagon of fashionable conceptions). We do not know how many questions a theory of coordination might answer, but we will know once we are pursuing such a project in an inter-disciplinary environment and with funding. We are convinced that an understanding of this technology in terms of coordination will benefit developments toward a human-centered society. Whether the path we then follow will still be guided by the vision of a society flooded by information is another matter. We seek funding for conferences, workshops, and individual seed projects to further this new kind of understanding.

5.7 Evaluative Techniques for Design

Design, through the technology it helps to realize, intervenes into future ways of being, into future coordinations of individual actions. Interventions of this kind can be costly and need to be justified in terms of the likelihood of actually introducing the changes they promise to cause in the lives of those affected by them, the stakeholders of the technology in question. The design of information technologies tends to call for large investments in research and development long before they can prove their worth and they tend to require the cooperation of many experts and users before these designs come to fruition. More often than not, the actual use of a technology tends to take directions that may not be predictable by their designers (see 2.0 in this report).

Design, like any future creating activity, rises or falls with the ability of designers to provide, together with the actions they propose, compelling arguments, evidence, test results, and defensible projections of what will happen. Engineers benefit from working within a narrowly circumscribed causally determined universe in which future behaviors of artifacts can be deduced from their structures, and their performance can be modeled, matched against desired functions, and measured in terms of efficiency, reliability and risks. Marketing too provides hard, albeit probabilistic, arguments, using statistics to predict markets and sales, for example. The discourses of these two disciplines, different as they are from one another, tend to rely on rigorous methodologies that are rarely questioned and readily adopted by outsiders of their profession. Design is different in these regards.

Designers, to be sure, always had a language to talk about the artifacts they designed. Historically, design discourse developed out of discourses from the arts, crafts, and architecture. With it, designers justified their artifacts in terms of their functionality of use and their aesthetics of form. However, the subjectivity of design arguments and the coexistence of numerous competing design philosophies made dismissing them easy. Outstanding design accomplishments were often based on personal relationships between famous designers and powerful businessmen and women, on sheer luck to have had the right intuition at the right time, not on hard evidence. These practices are no longer viable.

Product semantics is one approach that has reoriented design toward the meaning of artifacts, interfaces in particular, their role in language and in ecologies and thereby introduced concepts that are, at least in principle, measurable. The use of the semantic differential to assess character (see Butter in this report), of protocol analysis to assess cognitive models in use, and of ethnographical accounts (of focus group conversations or from comments obtained in more natural settings) to assess people's conception as they talk with one another and of their artifacts, exemplify the beginnings of a compelling and not so easily dismissable design discourse. An important addition to these techniques, merging the design process with a method of evaluation, is the use of stakeholders in design (see 3.0 in this report). Especially when the success of a system depends on the cooperation of diverse users, inviting representatives from relevant user communities as participants into the design process (see 5.4 and 6.5 in this report) provides one additional if not the only assurance that the systems under consideration will afford users' conceptions.

Developing compelling justifications for the designs of information systems presents considerable challenges, especially when these systems are

• information-rich and complex in technology, and hence, require considerable user competencies,
• have few known precedents for users to orient themselves by,
• must afford very many different stakeholders' conceptual models,
• will have to be working in a technological culture not yet existing, and
• are anticipated to develop a life of their own, including to grow like projects or social movements do.

In as much as the design of such systems becomes more and more prevalent, reaches further into the future, and involves higher risks of failure, especially for directing future development efforts, it would be highly desirable to support research on the development of evaluative techniques that are as rigorous as they can be — without deviating from the human-centeredness of design. Projects for the development of such evaluative techniques may parallel an ongoing project that develops a technology of the challenging kind mentioned above. The ability to make compelling arguments is the key to the respect designers earn within multi-disciplinary teams and to their ability to contribute to the information revolution that surrounds us all.

5.8 Federal Support for Research in the Design of Human-centered Systems

In 1990, US Congress decided on a national agenda to further efforts in research and development of information technologies. The High Performance Computing Act 1991 established the Federal High Performance Computing and Communication (HPCC) Program which is carried out by twelve Federal agencies. Its 1997 budget is in excess of one billion dollars of which $249 million are earmarked for R&D of Human Centered Systems (HuCS) which is an increase of 32% over the 1996 budget. The National Science Foundation (NSF) collaborates in HPCC’s effort by contributing $58 million to HuCS and its applications.

As defined, HuCS R&D makes computing systems and communications networks more easily accessible to and useable by a wide range of user communities. These communities include scientists and engineers, educators and students, the workforce, and the general public. Technologies enabling such systems include:

• “Knowledge repositories” and “information agents” for managing, analyzing, and presenting massive amounts of multimedia and multi-source information;
• “Collaboratories” that provide access to knowledge repositories and that facilitate knowledge sharing, group authorship, and control of remote instruments;
• Systems that enable multi-modal human system interaction including speech, touch, and gesture recognition and synthesis; and
• Virtual reality environments and their application to fields including scientific research, health care, manufacturing, and training. (Toole, 1996:26)

Major activities are reflected in Defense Advanced Research Projects Agency (DARPA) programs in intelligent Systems, where the intent is to develop modular human language technologies to support easy, low cost, rapid technology transfer and application development for document understanding, machine translation, and speech understanding. In the Intelligent Integration of Information area DARPA supports the development of tools and techniques to enable the rapid construction of information fusion, aggregation and summarization software. DARPA extends and evaluates large-scale statistical modeling, machine learning, and knowledge representation methods for spoken and written language understanding and develops hub formalization that will infuse existing programming languages with new advances in formal methods. They continue the experimental evaluation of design technology for high performance computational prototyping of systems.

NSF, National Aeronautics and Space Administration (NASA) and DARPA continue the Digital Library projects. This research seeks to develop real-time image understanding algorithms for use in image registration, target recognition, and autonomous navigation for ground level and overhead reconnaissance and surveillance and to implement initial toolkits for development and evaluation of highly interactive, agent and dialogue-based human computer interactions.

The NASA IITA program, which includes some HuCS activities, will be completed in 1997. NASA, working collaboratively with other Federal agencies whose primary focus is HuCS, continues to invest in the area of Human Centered Systems using expertise from its Information Technology Center of Excellence. These investments will be through some of NASA’s more traditional efforts such as computational aerosciences.

NSF has increased support for research in information-based learning technologies that have the potential to transform education at all levels in the 21st century and form a new enabler for the integration of research and education. NSF has initiated the multi-agency program STIMULATE (Speech, Text, Image and Multimixed Advanced Technology Effort) in order to understand multimedia human communication and apply it to computer technology.

National Institutes of Health (NIH) continues its Telemedicine and Visible Human programs and develops
and tests a graphical user interface for an existing medical imaging system. National Library of Medicine (NLM) begins projects for the full object identification of the Visible Human data sets. National Center for Research Resources (NCRR) is defining the requirements for establishing and evaluating two or three collaboratory testbeds (possibly with NSF and DARPA as partners).

Department of Energy (DOE) is providing a prototype integrated, distributed multimedia scientific visualization environment for HPCC researchers by integrating existing collaborative tools into a virtual Laboratory Framework.

National Institute of Standards and Technology (NIST) is supporting projects on models, architectures, conformance testing and collaboratory technology supportive of manufacturing integration, information metrology, and improvement in the accessibility of standard reference data and algorithms for scientists, educators, the workforce, and the public.

Department of Education (ED)'s National Institute on Disability and Rehabilitation continues the funding of 15 continuing and one new Rehabilitation Engineering Research Centers (RERCs). These centers support programs designed to conduct research, demonstration and training activities. RERCs focus on issues dealing with rehabilitation technology, including rehabilitation engineering and assistive technology devices and services.

Agency for Health Care Policy and Research (AHCPR) supports research into the barriers to a successful installation of comprehensive health information systems, emphasizing the speed, cost, and human factors that affect success to accelerate the transfer of computer-based information technology. The Agency will evaluate the medical effectiveness and economic impact (cost benefits) of automated clinical decision support systems in diverse care settings. (From Toole, 1996:30-31)

References


6.0 Overview

Following are the reports from five working groups. Four were formed by assigning participants to given topics and a fifth emerged spontaneously. They reflect not merely different concerns but also different working and reporting styles. Some preferred a narrative of what had been accomplished, some sought to preserve the flow of the discussions, others extracted the most important propositions that future readers might consider separately. These reports constitute a bridge between the individual papers of section 7 of this report, which had been prepared in advance of the workshop and presented during its proceedings, and the recommendations in sections 2 through 5 that emerged from the workshop as a whole.

Working Group One, on information design, developed a taxonomy, proposing a series of distinctions on the levels of primitives, compositions, users, uses, attitudes, and references to information.

Working Group Two, on design methods and technology, explored the changes in tools available to design, from what a draftsman had to computer aided design (CAD), suggesting, however, that there currently are far more design tools at hand outside computer applications.

Working Group Three, on design education, developed some forty propositions on what should be done to bring design education into the 20th century.

Working Group Four, on design in the future, addressed what an information society is most likely to demand of designers in the next decade and ended up proposing research to electronically network designers and design educational centers to enable collaboration internationally.

Working Group Five, on collaborative design of collaboration, developed and simultaneously reflected upon processes of collaboration in design and proposed a self-reflexive way of cooperating, called an Ouraboratorium. This is intended as a reproducible social practice that, when embodied in human interaction, becomes not only its own artifact but also an attractive way of designing a variety of other cultural artifacts.
6.1 Information Design

Members of Working Group One were:

- Tice DeYoung, NASA
- Linda DuBois, NCSU
- Austin Henderson, Apple Computer
- Lorraine Justice, OSU
- Charles Owen, IIT
- Gary Strong, NSF
- Jay Tomlinson, NCSU

Most of the group's time was spent discussing an architecture of information: How information might be defined, what shapes it takes as the result of that conceptualization, and the tools needed for working with information (information technology). These topics, we felt, were central to the workshop and could provide an ontological frame for further work.

As an architecture of information raises more questions than we could answer, we chose to present our report by outlining the issues we discussed and posing questions that will have to be answered elsewhere. Thirteen issues received the attention of the group: ontology, taxonomy, identity, mutability, structure, presentation, scale, dynamicity, rights, validity, status, actions, and pragmatics of information use.

**Ontology.** Of utmost concern is the question of what we take information to be. Specifically, what ontological commitments do we make as we engage this broad problem of understanding the "stuff" we regard as information?

Firstly, what is information? In which ways does information depend upon the environment of its creation? One view is that the environment is best characterized by the genre within which the information arises. For example, a formal memo is different from a note, even though both might be sent by e-mail and use the same words. As genres develop over time, the meaning of information may subtly shift. We explored:

- What is information?
- What genres of information do exist?
- What does it mean for information to be "of a particular genre"?
- What media characteristics enable a genre to be defined?
- How do genres develop and change the status of information?

Secondly, how is information created? Is it created at the time of writing? Is it created at the moment of reception (reading, decoding)? Or is created after someone asks a question to which it could be seen as an (the?) answer?

- How is information created?
- What forms does it take out of asking?
- What forms does it take out of will?

Thirdly, how do people understand information? What is their conceptual model of it? Using a physical or mechanical model, one might see information as having size (mass), being made of parts which are connected to, and have effects on, one another. An alternative computational view would direct attention to the processes information sets in motion, doing intelligent work, for example, or the information "products" it produces.

- What are users' conceptual models?
- How might mechanical processes serve as metaphors? — understanding information in terms of having parts, velocity, location, being causally related, complying with physical laws, having instant effects.
- How might computational processes serve as metaphors? — understanding information in terms of procedures, interpreters, states, transformations, decisions, flow.
- How might linguistic processes serve us as metaphors? — understanding information in terms of propositions, stories, instructions, declarations, subject to grammatical/syntactical composition rules.

Fourth and finally, ontological models among which we might choose entail very different approaches to conceptualization of information, and offer very different views on the tools we might have to develop to manipulate information. Specifically:

- Objects have relations, properties, associations, whereas
- Neural nets have probabilities, nodes, fields, and
- Well-formed propositions satisfy certain logical requirements of form.

**Taxonomy.** Although strongly dependent on the assumption of a particular ontology, another issue concerns the classification and organization of information. What is the nature of suitable classifications? What features are distinguished on different levels of the taxonomy?

A recursive definition of information is a good starting point to shed light on what a classification may accomplish. Accordingly, we explored a definition of information as a taxonomy of kinds of information. This recursive definition involves six taxonomic levels:
Level 1: Primitive components.
- Pieces of text
- Graphic still images
- Animations
- Audio

Level 2: Compositions of pieces of information groupings. Note that choices on this level need to be made about how much internal structure is the property of primitives, as opposed to the property of compositions (for example, a graphic image may be composed of smaller graphic images).
- Documents
- Arguments
- Statements
- Pleas
- Claims

Level 3: Users of information. Individuals in particular roles, groups, and institutions who represent directed uses of information are themselves a matter of information.
- Individuals acting with purpose
- Individuals in roles
- Social groups
- Organizations
- Institutions

Level 4: Uses of information. Instances or activities of using information (acts of finding, copying or presenting something) are information as well.
- Searching text for the information it could provide
- Creating new from old text, preserving information
- Copying text to copy information
- Deleting text to eliminate information
- Adding text that supports, confirms, or invalidates information.

Level 5: Attitudes toward information. All relationships between people and information are also information (e.g., John believes that 2+2=4).
- Believe, disbelieve, doubt
- Like, dislike, love, hate
- Care, don't care

Identity. When is one piece of information the same as another? What gives information uniqueness? Or is this even a well-founded notion? Ownership requires the concept of identity, and other high-level concepts also depend on a well-defined notion of uniqueness.
- What makes pieces of information different?
- How much difference is enough?
- What part does time play?

Mutability. How much does it take to change one piece of information into another? When does it stay fixed, and when can it change? Is well-definedness the same as being resistant to mutation?
- When does the information stay the same (how "large" can changes be to remain insignificant)?
- What are the transformations under which information stays invariant?
- How is change of information or its transformation signaled?

Structure. When information is regarded as structured (for example, when it is compositional), additional concerns arise: Is the structure dynamic or fixed? How does it come into being? Are there boundaries within it? What is its scope? Some examples we discussed include hierarchy, classifications, webs, maps, and relations. What are the advantages of static structures? What of dynamic structures?
- How are structures induced automatically by acting? asking? searching? or browsing?
- What kinds of boundaries can be created within structures? What creates them?
- What is the value of layering? When is it feasible, when not?
- What is the effect of increasing "extent" on different aspects of structure? Specifically: hierarchy, classification, webs, maps, relations

Presentation. It is natural to think of information as separate from its presentation. That is, there is a commitment to the information being something that can be displayed in many different ways (same information, different presentations). The question is how these presentations are produced, including dynamic diagrams produced by pushing information through templates.
- How can presentation be customized to users?
- Can the "presentation" of information be associated with the "content" of information?
• What is an architecture of views?
• What is an architecture of diagrams?
• What is the potential of dynamic diagrams?
• How far can real time and three dimensions expand the power of diagramming?
• How can dynamic diagrams be formed by extruding information through template processes? What are the new forms of such templates?

Scale. As we think about the huge spaces of information being made available through the web, the notion of scale becomes key. In particular, in a distributed, dynamic environment, there is little hope of making a statement about the whole (for example, How many pages are there? Is there a page named “funglesby?”). Scale renders the intuition of “the whole” questionable. We probably have to always think in terms of subsets of the (a?) whole.

• What does it mean to realize that you can never get to it all? How does that change other premises?
• If information is always changing, how does scale affect the means for effecting change?
• When does the term “impractical” come into play? How big is too big? How long is too long? How many operations are too many?
• Can the effects of scale be offset by dynamic participation of many effectors?
• Is there an optimum growth in scale that can keep pace with the growth in number of participants in a system?
• How can an open system be maintained at very large scales?
• What is a practical “whole” when the term is not well-defined at large scale and is essentially partial?

Dynamicity. Distributed information cannot generally be understood as having a single “state.” Subsets, under constrained conditions, can generate a coherent notion, but how? We discussed the problem of “knowing” the condition at any time for the purposes of reconstruction.

• We assume the notion of “state” is not well-defined.
• We assume that you cannot capture a state (you may be able to for some subsets, but not for all and, in general, you cannot) — in any case, do not count on it.
• What produces stability? How can a “slice” of the system be taken at any time? Can some kind of system-wide synchronization be introduced?

Rights. What sort of rights are associated with information? Who has them? How is the association achieved, reassigned, or altered? What does the legal system have to say about rights to information?

• How should ownership be defined? What does possession mean and where does this come into play?
• How are intellectual property rights established and indicated?
• What does it mean to be a “creator”? To what extent is the one who “understands” or “interprets” a phenomenon entitled to property rights?
• When does a “user” acquire rights because of unique uses made of information?
• Can some kind of refined hierarchy of rights be built on the concept of <action>er for any <action>, where the action involves a kind of operation on the information?

Validity. Over what period of time does information stay valid? And for whom? For what purposes? Both uses of information including needs for up-to-dateness as well as historical preservation should be considered.

• How is validity indicated?
• How can users establish validity within their own frames of personal reference?
• How is time best used in establishing validity? Does duration have meaning beyond the period between changes?
• How should bias be accounted for in issues of authenticity?

Status. What is the status of information? (E.g., is this a draft? Version 3? or final? Is it fixed? or changing?). Is status a property of the information or is it imposed from somewhere else? Can you recognize it in presentations?

• Is there an ontology of status?
• To what extent is status intrinsic to a piece of information? Inherent in views of the information?
• What is the best way to indicate status in a presentation, specifically: in drafts? final versions? signed documents?
• What is the status spectrum between mutable and fixed?

Actions. Information is not just there, it must be understood as such and be acted upon. Actions taken are part of the definition of information (for example, if
you cannot find the documentation, then it is not documented). Actions take time, cost resources, may be only partly completed at some juncture. Particular actions we mentioned included locating information, accessing it and presenting it.

- **Actions take time (duration, latency); things move (with speed); actions cost (resources); actions may be repeated (redundancy).**
- **What can be learned from a history of actions?** Specifically: how can we keep track of location, where information was, where it is now, who else accessed it, how often was (is) used
- **How can search actions be facilitated?** To what extent is search a function of ontology? Specifically: How do we best employ structure, properties, contents?
- **How do we gain access to information?**
- **What methods can be used to present information?** In the sense of dynamic diagrams, would an “extrusion model” be a good metaphor: Data pushed through a shaper or template to produce a view?

**Pragmatics of information usage.** For any of this to touch the real world, there are a number of pragmatic concerns that cannot be overlooked. What will insure that the means for information storage will last longer than a few decades? What insures that the devices for presenting information are available at reasonable prices, are within the control and knowledge of the user, are properly supported (serviced and associated with other peripherals), enable collaborative uses, and are appropriate to the cultures of the (targeted) user groups?

- **How can longevity of information be assured, given the impermanence of contemporary storage media, the dependence on specialized transfer and recovery machines, and the ever-changing media forms?**
- **What practical actions can be supported to manage risk?** Specifically: to prevent loss through reproduction, to maintain copies of current versions while work on next versions is in progress?
- **What is the nature of devices to best connect people to information?** To what extent are they describable? available? ubiquitous? controlled? or owned?
- **What is appropriate operating power?** How much should it depend on assumptions of usage? What is a good definition of “usable”? How cognitively undemanding must the interface between user and information be? Is it enough to be able “to do the job”? What is affordable?

**Conclusions.** With these dimensions of information in mind, we finally came to address questions concerning the properties of an architecture of information. Clearly, this architecture must respond to all of the above dimensions, but, because there is no single right way to choose a value on any one of them, the architecture must somehow encompass the full richness of all. We are making three general recommendations, all of which are founded in the concept of openness (also see 3.6 in this report):

**Heterogeneity.** An architecture should be heterogeneous.
- It must not embody a single viewpoint or ontology, but should instead encompass many.
- It should accommodate a variety of architectures within its structure.

**Extensibility.** An architecture should be extensible.
- It must not fix the terms of description, but instead be open to new and evolving ones.
- There should always be room for another distinction.

**Inclusiveness.** An architecture should be fully inclusive.
- It should be independent of “content” and “form.
- It should not be constrained by particular structures of presentation.
- It should be definable over all other architectures.
- It should be able to hold anything.

6.2 Design Methodology and Techniques

In Working Group Two, the following participated:

- **Suresh Bhavnani**, Carnegie Mellon
- **George Cybenko**, Dartmouth (Moderator)
- **Pat Fitzgerald**, NCSU
- **James Lester**, NCSU
- **Philip Smith**, OSU

The group started out discussing the shortcomings of computer interfaces and software. It was agreed upon that if the goal is to design better software and interfaces, then it is important to study the user from the beginning of the design process. Another point was that the display is not the only interface, it really includes the broader environment of the user. Also the
users' past experiences and knowledge affect the way they will use technology. All of this needs to be studied and understood before the design process begins. There is also a need to examine and rethink the whole atmosphere in which new technology will be used. If the goal is to make better systems, then the design process should begin with empirical data.

An example of this is the traditional draftsman that tries to switch from the T-square and pencil to CAD. Draftsmen often are very inefficient and do not use the technology to its potential because they tend to think of drafting in terms of their traditional approach to drawing lines by hand which can become very inefficient when using CAD. To become faster and more versatile, the new tool requires that users learn a wholly different process of laying down lines. To design a better interface for them, it is important to know how draftsmen think, what processes they are accustomed to, and then build an interface based on this understanding. However, educating individual users on the efficient use of new tools, will always remain important.

The group switched over to talk about the design process. It was determined that design methodology is not the same across the disciplines. It is important to come up with an iterative process. Computational technology can speed up iterative process to the point of changing design quite drastically. The benefit of this technology is that its user does not have to repeat processes or rebuild objects as often as was necessary in traditional processes.

George Cybenko presented his comparison of design methodologies (the same overhead he used in his presentation to the whole group, not included in this report). The following discussion was sparked by his overhead. His main argument was that there are more building blocks in the real world than there are in the computer world. For example, if a person was going to build a box in the real world, there are many different materials such as woods, plastics, metals and so on with more alternatives within each class of materials such as oak, pine, etc. in the woods. If this were compared to computers there are not as many possibilities to accomplish tasks. This argument was debated for quite a while with a conclusion that the computer world was growing very rapidly and that indeed in some realms there are probably as many building blocks as in the real world, but the problem seems to be finding them and learning how to use them. Better indices and searches need to be developed to overcome the gap between available information and the user.

Because of the gap between available information and users as well as the learning curves of most software users, it is hard to estimate the cost of a project that is using new technology. It is unlike in the design of traditional industrial products where we have lots of experience with specific tasks, making it easy to estimate time and materials needed to complete a task.

When users have invested their time in learning and becoming familiar with a particular software package, it is costly to introduce new software that requires changing established habits. This is pointing to the need to either grow standards or commands that are common across all domains in the computing world or to define changes as expansions or elaborations of existing command structures, rather than as replacements of previous ones. This would make newness less disruptive and users more versatile.

Computers are hard to recycle. Many things in this world can be recycled, but not software nor many hardware components. This is an issue that needs to be considered. For example, by making it cheaper to upgrade hardware and software instead of buying a whole new machine with new software every year or so.

In the digital data world such as GIS uses, it is hard to find the data needed for a specific project. Many organizations have things digitized in various different software packages, however nobody seems to be putting the different pieces together in one place so that it can all be accessed.

Concerning further R+D work needed in design (and of design), not necessarily requiring NSF funding but certainly attention, the group wants to note the following points for further consideration:

• What are areas we need to invent new tools for?
• Are there new kinds of tools typical in an information society that are not mere elaborations of those used in our current industrial form of society?
• Can we develop search tools for accessing available data in particular knowledge domains?
• What kind of standards on tools do we need to develop? Do we need something akin to software conversion packages for tools?
• Should every software package come with a standard or individualized set of tools?
• Functionality has come into question. Do we need to clarify what function means in an age of information.
• How do we know whether or not information is accurate?
Who is responsible for information?
Can information be owned? Should it be? and by whom?
What aspect could or should be owned? Access? its reading? its reproduction (forwarding, distribution)? its application (with or without profit and to whom)?
Will there be a way of keeping track of information use? Should this be made possible and for whom?
Interfaces and functions need to be tied together.
In education, it is task completion that needs to be taught, not commands and icons.
Continue funding multi-disciplinary activities.
Design needs to be grounded in empirical data. What is needed is a language for clarifying the kind of data relevant to design.
Tools shape behavior and people tend to build what tools do easiest. This greatly affects design and should be considered when designing interfaces.
Designers should keep global perspectives in mind and try to overcome the common tendency to develop things foremost because tools for their development are more readily available than for other things.
Past experience and education affect how people use computers. This too needs to enter design considerations.
One problem with the web is that it is driven by people that want to put something out there and not by people who want to search for what is in there. This makes searches very hard. Better search methods need to be developed.
Infrastructures that support multi-disciplinary efforts in design are seriously lacking. We need funds or other forms of encouragements for all kinds of ways to cross the boundaries between the government, the private sector, universities, departments, as well as those professions that have not traditionally worked with design, like journalism, etc.
Research is needed on how to create population-wide information literacy (user cultures) while building a new education system on the information literacy gained.
Designers need to know more about the users. Collect empirical data and use it in modeling users' needs and use of information.
The design process should be studied systematically to evaluate its productivity. If found inadequate we have to come up with more productive processes.
We need to create more documentation of successes and failures of design so other designers will not repeat mistakes. Information technology is making this possibility increasingly attractive and feasible.

The group wants to add some comments on the workshop: Overall, the idea of it and the conference as such was very successful. However, many of the presentations and discussions were not grounded in praxis and too abstract. Also, participants in this group felt constrained by a seemingly prevailing phobia associated with its topic, Methods and Technology, which might explain why only a few workshop participants choose to be in this group. Finally, the group felt the professions were under-represented in the workshop.

6.3 Design Education

One of the larger working groups dealt specifically with design education in the information age. Considering the dramatic changes brought about by new information technologies alone, the next 10 years are of pivotal importance for the role design and designers will play in the evolution of society, its infrastructure and its economy.

While some of the points listed below as a summary of the discussions are more obvious than others, it was the clear consensus of the group that design education (in the broadest sense of the word) requires special attention, or else the opportunity to integrate information technology in the everyday life of people is missed.

No professional discipline depends as much on advances in technology as design does. Design concerns itself with the entire range of uses and users of spaces, products, display of information (graphics) and communication systems. Major shifts (e.g. from efficient engineering of functions to a concern for meanings and user interfaces and the attendant shifts from a first- to a second-order understanding, and from hierarchical and linear to heterarchical and recursive ways of thinking) require a new kind of knowledge, a new kind of practice, and a new kind of discourse that future-oriented educational programs must take most seriously if not pioneer. The participants of our discussion group agreed on the need for quite radical changes in current design curricula, pedagogies, and academic structures.

The points made during the discussions, to the extent not included in the recommendations (Designing Design Education in this report), are reflected in the following 40 'bullets.' These have been extracted from tapes of six hours of lively discussions among the working group's participants, many of whom
are leading educators in design, administrators of major educational programs in design, but also design practitioners with strong concerns for educational issues:

Daniel Boyarski, Carnegie Mellon
Reinhart Butter, OSU (Moderator)
John Cerniavski, NSF
Meredith Davis, NCSU
Joe Henderson, Dartmouth
Haig Khachatourian, NCSU
Joseph Koncelik, Georgia Tech.
Ingrid Limmer, OSU
Julia Malik, MIT
Noel Mayo, OSU
Bill Rathbun, NCSU
John Rheinfrank, SeeSpace
John Tector, NCSU

• Design in the Information Age has much if not everything to do with education. Thus, support for design education deserves the highest priorities, including those of funding.

• Differentiation between ‘formal’ and ‘informal’ education or learning emphasizes the fact that gaining knowledge and skills starts well before elementary education and is a lifelong endeavor.

• An initiative, started in Britain in the late sixties, added ‘Design’ to the ‘three Rs’. Planning, creating, and visualizing (drawing) should be considered as basic as Reading, Writing, and Arithmetic.

• Current and anticipated developments in the job market add urgency to the need for providing design education in the above sense on an ongoing, that means lifelong, basis (continuing education, etc.).

• This raises the question, among many others, of new delivery models, since many of the present educational models seem archaic and entangled in bureaucratic structures such as traditional lecture and studio courses and curricular sequences, quarters vs. semesters, degrees and licensing, but with far too little regard to the emerging technologies.

• Education and learning must be broadly accessible ('letting people in, not adding them out'), with the goal of nothing less than a 100% success rate — considering the growing expense of education.

• Scrutinizing current content for its future significance should produce both formal and informal curricula without the weight of merely traditional, and now rapidly antiquated, subject matters.

• Specifically in design, attention must be given to all 'stakeholders' involved in a particular technology, whether they use the technology, whether they facilitate its use (producers, sales and marketing experts, educators and commentators), or whether they are concerned with the consequences of its use (ecology). (See design principle 3.0 in this report). Anything less is irresponsible.

• The belief in being able to go all alone is often the cause of failures and in any case an arrogant attitude.

• Design education must emphasize teamwork, possibly on an inter-disciplinary level (see design principle 3.5). Since designers are crucial in contributing to the success of a product or system, especially where it must interact with users, designers need to understand and be able to communicate with experts from different disciplines and be able to assert their own expertise in collaborative settings.

• Based on the designers' strength to 'see things comprehensively' and 'cut through complexity,' largely from the perspective of human users, designers should be taught how to be project leaders or product development managers. This requires a knowledge of cooperative techniques that are rarely provided in current design curricula.

• Design is almost synonymous with cooperation. Education should embrace this empirical fact and research should be directed towards improving cooperation across disciplines.

• Cooperation needs to be practiced, not merely taught. It may start with professors teaching courses together with professors from other disciplines, but must end up in collaborative work across departments, including with representatives of industry, government and ordinary users, where appropriate. Collaborative work is well worth funding as they may provide demonstrations as well as data for critical examinations.

• It is unfortunate that other professions in the product generation processes lack understanding of design or have outdated conceptions of what
designers can do. This often means that the development of systems is driven by technology and less by how they should interface with users and which role they should play in society. Unless this problem is addressed soon, this ignorance might be carried from the industrial age into the information age.

- By demystifying 'design' and making it a basic 'R', taught and promoted as such, design might become more naturally accepted, just in the way mathematics is — while making neither designers nor mathematicians obsolete.

- Designers must not feel threatened by the paradigm shifts the information revolution necessitates. Instead, they should consider themselves freed to focus on their unique areas of competence and contribute to tangible solutions — regardless of the popular misconception of designers as experts in the beautification of two- and three-dimensional objects.

- The new emphasis on information requires a radical change of attitudes, not only in design but also in the other disciplines concerned with developing new technologies. These disciplines may be in need of redefinition as well.

- Divisions of labor along traditional boundaries are quickly becoming obsolete. Interface design, for example, bridges graphic design, product design, systems engineering, linguistics, cognitive science, as well as anthropology. This weakening of boundaries calls for even more radical changes in educational structures and systems.

- Design departments can no longer educate designers all by themselves. An essential part of design education has to be cross-disciplinary. This includes contact with government and industry as major stakeholders who may serve as the trigger of the needed changes. How to institute these cross-disciplinary connections is a valid subject of research.

- One practical option might be to broaden the base of undergraduate design education, while letting graduate design education focus on research and specializations that have the flexibility to respond to demands from the field.

- Research and publications are the lifeline of any established and respectable discipline. Without generating written records of design activities, without producing a teachable body of literature, in other words, without a continuous professional discourse, design is not likely to be taken seriously by other disciplines, and individual designers are left to fend for themselves. Developing a design discourse that provides the intellectual strength of the discipline falls squarely in the domain of education, or has at least to start there. This is to keep up with other disciplines whose discourse develops continuously and with progressively improving strengths, like in medicine, for instance, which too is an ultimately very practical discipline.

- As pointed out by another working group, research in design must include applied subjects with direct benefit to the 'real world'. Drastically raising the current funding level by industry, private foundations, and governmental institutions is one way to keep design education grounded while at the same time increasing educational opportunities.

- Collaborative student design R&D projects as well as contract R&D projects could be both a financial basis and an incentive for career enhancement and changes through higher and continuing education.

- The question of Ph.D.s in design is directly related to research and its funding, as it is in any other discipline. US educational programs offering a Ph.D. in design, currently less than a handful, will not succeed without solving the funding issue. Compared to this, other (more philosophical) barriers seem trivial.

- The success of design R&D efforts increasingly depends on being situated in information-rich environments — meaning increasing access to advanced information and computational resources.

- The worldwide availability of high capacity communication channels is likely to radically change the design process and design education as well. The future ability to search among 3-D solutions to particular design problems worldwide, inexpensive access to all kinds of experts on the technology under development, virtual reality simulations of possible system uses, the ability to communicate information needed to create prototypes anywhere it is feasible to build or test them, etc. completely relocates the resources traditionally provided in design departments and changes the shape of design education.

- With an observable trend towards decentralization, new collaborative technologies are opening up new
educational options. However, there will always be a need for face-to-face presence and personal contact — at least for periods of time (critique sessions, studio experience, especially where relationship issues are important).

- Upgrading institutional learning environments, providing at least some good examples for orientation and demonstration purposes, and offering ways of doing research into the process of learning design is a worthwhile funding goal.

- Centers should be established, first nationally, later internationally, to optimize the modeling effect of the obviously large investments needed to bring design into the next century.

- Emerging information technology would allow remote access to the above centers at all times and in 'multi-sensory' ways — even to the point where 3D models can be viewed holographically and created by NC milling, etc.

- The social consequences of such extreme use of information technology needs to be carefully studied before it is adopted widely. Virtuality may not be the appropriate answer to all or even most aspects of design education.

- What definitely does work is the use of currently available electronic media for interactive teaching programs. Many subjects taught conventionally by instructors in classrooms to students, requiring substantial organizational and other effort, could be more effectively conveyed on-line, etc.

- Technology by means of simulation or animation might even improve reality, and thus effectively enhance the learning process.

- Copyrights and other issues of rights and ownership as well as the complex financial matters related to formal and informal education today need extensive study, but also provides opportunities as yet unrealized, especially for the underprivileged sector of the population.

- Systems of all kinds have the potential of becoming powerful mediators between people, creating a new sense of participation, as long as they are conceived and designed with simplicity of use in mind.

- Product semantics is one powerful new effort to accomplish human-centered design, if not THE quintessential effort. (See 3.1 in this report)

- Improvements in interface design have been impressive. However, seamless interaction in an environment that seems as natural and obvious as talking through a telephone is far from being reached and should be considered as only one step towards making universal access possible. The others being economic, political, and above all cultural (a conducive user culture).

- New input/output options for electronic equipment currently in development will foster miniaturization and universal access. Combined with progress in artificial intelligence, among other currently active disciplines, future information products and systems are making universal access increasingly likely, whether through ownership or leasing.

- Universities as technological brain centers rather than as 'student factories' are a fairly realistic prediction. The trend has already begun with downsizing faculty and other personnel, and investing in information technology instead.

- Design education, defined in whichever way, should be at the forefront of experimentation with the human use of technology, developments in learning, and collaborative techniques. Its relative youth as a discipline requires that it maintains its openness and its flexibility. Its growing significance during the ongoing information revolution attests to the respect, attention, and major funding it deserves.

### 6.4 Design in the Future

Members of Working Group Four were:

Alison Andrews, UPENN  
Kermit Bailey, NCSU  
Frank Biocca, NCSU  
Charles Burnette, UArts  
Hartmut Ginnow-Merkert, Khs Berlin-Weissensee  
Lorraine Justice, OSU  
Patrick Purcell, Imperial College  
Susan Roth, OSU  
Iris Schoell, NCSU  
Richard Jay Solomon, MIT  
Walter Wiebe, MCNC
Framework for Action

This group discussed a proposal for a research program that would establish a virtual design institute. This program would involve the following major activities:

- Design, develop, build, test, debug, use, support and evaluate an interoperable, open, networked, multimedia, interactive education and collaboration digital, virtual design school.
- Integration of learning tools, collaborative technology, simulation/ virtual environments, into a virtual learning/discovery studio and laboratory.
- This effort would require the expertise of researchers, computer science, engineering, education, digital librarians...and design researchers and educators.

The experience and knowhow developed through this program would provide actual insight into requirements for building a distance design learning system, and build awareness into additional critical research to achieve an effective virtual school of design. Shareholders for such an effort would include government research agencies, industry and university faculty and students.

There were also similar discussions about a virtual design school for the Information Age. ADONIS was an initial description of an overview for research proposal.

Advanced Design Objectives for a New Information Society (ADONIS)

ADONIS is a proposal to adopt a design-led strategy to respond to the impact of change wrought by an increasingly pervasive digital infrastructure and further, to consider the implications for design education and design practice as the digital revolution begins to affect the performance and the structure of future products, systems and human habitats. The digitally induced change can be viewed as a triad of linked change agents. The first agent of change is an analogue/digital transition as we move between a world of largely analogue media to a fully digital context.

For designers, it is inevitable that this hybrid analogue/digital transition will cover a brief period of using passe design techniques (based on traditional and familiar analogue metaphors) in a variety of new digital projects, an effect often described in design methodology as the “horseless carriage” syndrome. A second agent of change is a feature associated with developments in new digital media in that the engine driving such development, (commonly referred to as “technology push”), has been progressively giving way to a more “content driven” scenario, in which the content domain becomes the source of the informing idea and provides the dominant contribution to the innovative product rather than mere technical competence or expertise, (irrespective of the type of application) whether it be new forms of electronic publishing, digital movie making, or on-line medical services.

A further agent of change is represented by the technology of “convergence”, in which computers, communications and new design media are being brought together in a way that will transform the manner in which we shall experience, in the future, the familiar media of today, such as television, movies and network-based telecoms services.

Given the impact of these three powerful, complementary “change agents”, (namely, digital infrastructure, “content pull” and progressively convergent technologies), now is the time to consider a special design-led initiative, which will investigate the future effect of these changes and address the challenge of creating new forms of entertainment, information and education systems and artifacts.

Within the development strategy of the ADONIS proposal, innovation would be shaped by creative design insights as a complement to the technical imperative. This has important implications for any design-based strategy, linking technology and applications. The principal raison d’être for ADONIS is to act as a catalyst for collaborative action research in those applications which can only be effectively tackled with a broad range of complementary skills and expertise, (including design, technology, psychology, the arts and the humanities).

The Form/Content Symbiosis. While it is often claimed that new digital media infrastructure will greatly modify the design of content, the countervailing proposition (reflected in this ADONIS initiative) is that new content structures will reciprocally affect the development of media technology in a major way.

The most important mission of the ADONIS initiative will be to create a design research context which will provide an arena for both feed back and feed forward in the frontier areas between the emerging technologies and the various application domains. In the ADONIS initiative, the basic concept is a premier international community of designers and associated disciplines across all the constituent specialisms (human sciences and technical expertise) that are needed for current project development.
The proposed forum will act as the venue to promote synergy between the creators, media technologists and the advanced communications community. The synergy represented by the ADONIS initiative would show real mutual benefit, both from innovative abilities of the design and creative communities and conversely and from the technical expertise of the information and communication technology sectors working together. Given the dynamic of current development in information technology, the basic element in the ADONIS initiative most valuable role will be to achieve an ever closer couple between design research and design practice and education. ADONIS would focus on the links between these design domains.

This draft proposal as well as other concepts that were discussed in this workshop could be applicable to National Science Foundation program announcements and other agency research agendas.

6.5 Collaborative Design of Collaboration

Recommendation for the design of an Ouraboratorium

An Ouraboratorium is a design group that collaboratively and self-reflexively designs through a recursive process. This ad hoc working group explored how such a design team might function.

Members of this group were:
- Douglass Campbell, Dartmouth
- Elizabeth Dykstra-Erickson, Apple Comp.
- Frank Galuszka, UC Santa Cruz
- Klaus Krippendorff, UPENN
- Susan Metros, UTennessee
- Elizabeth Sanders, Fitch Design

In line with the Design@2006 workshop goals, our Ouraboratorium was designed to wonder about the process of designing. Through recursive refinements, reformulation after reformulation, wondering about design turned into designing, into the designing of design. As we imagined the participants and conditions for an Ouraboratorium, we found ourselves little by little drawn into designing them virtually, as we went around, revisiting, rerevisiting, rerevisiting, etc.

The participants in an Ouraboratorium would gather around a problem, a question that was pertinent to that particular group of people. The participants would be varied, and would be selected or be self-selecting to reflect the variety of an imagined larger population of stakeholders and users in this microcosm (see 3.0 in this report). The Ouraboratorium would be directed according to the principles of a “floating hierarchy,” that is, a heterarchy in which leadership shifted according to the appropriateness of the characteristics of the “problem at hand” — as consensually determined by the group. The participants would ideally be a cluster of cyberneticians who also exemplified another discipline or disciplines that was pertinent to the task. Thus, each participant would be a constellation within a constellation. As an integrated variety within an integrated system, the Ouraboratorium would seek to satisfy the law of requisite variety (Ashby, 1956; also see 3.4 in this report).

So, an individual participant might be a member of a certain profession, a scientist with pertinent expertise, a member of a race, age group, gender, and geographic locale, as relevant, and also a cybernetician, with hopes that each cybernetician would bring with her the imagined discourses of, say, an area of knowledge, a user community, an industry, or a public, and could contextualize them, as well as contextualizing her own biases, especially with a helpful reminder from other comparable specialist/non-specialists.

An Ouraboratorium might be self-organizing. It need not be. In either case, an initial bias would be felt in its structure and composition — as people would self-select or be selected with an efficiency of purpose in mind, and, as a purpose is likely to have, if even vaguely, an end in sight that might torque the selection, it was suggested that, included in an Ouraboratorium should be an unpredictable member, a so-called “wild thing.” The wild thing would question assumptions as they form, would challenge the boundaries of disciplinary domains as otherwise understood by the participants, and cheer the seemingly unthinkable. The child who commented that the Emperor had no clothes, is a sort of wild thing, as is the court jester, and the artist in society. The wild thing, to be truly wild in the desired way, should *not* be a cybernetician.

The Ouraboratorium would meet and meet, and meet again, revisiting the whole situation each time, developing it incrementally as a whole, assessing it each time from the standpoint of a specialty, generation, gender, etc., and with cybernetics as an overarching self-reflective frame, acting to contextualize each reformulation, design, and plan. Besides meetings, the Ouraboratorium would provide private spaces into which participants can withdraw to do their own thinking, undisturbed, yet in constant awareness of the role of other participants’ conceptions and cognizant of the
resources and challenges the Ouraboratorium can make available to each of its members.

The Ouraboratorium encourages its participants to oscillate between taking **global and local perspectives**, being an involved participant and a reflective observer, and acknowledge the possibility of conflicts between different stakeholders’ interests.

In this short development, our group, — which evolved quite unlike those designed from the top down and given specific tasks by the organizers without member input — already existed as the kind of Ouraboratorium we propose as a way of designing. It was directed toward the idea of design and came to **design as its own consequence**. For example, we were drawn to formulate the role of design in view of the Internet, which appeared in conversation as a new kind of democratic system. Only a year later, the prevailing opinion of the Internet seems to have changed from excitement to sourness, judging by the narratives that have emerged since. This is the fate of many systems that are information based. What remains of design is a dialogical or interactive process that must attract its own stakeholders who would carry it forward (also see 3.0 in this report) or fail.

The Ouraboratorium is a **self-acknowledged cultural artifact**. It will of necessity create and recreate itself in a culture of its own making. It will thus be guided by sensibility, the aggregate of developing allowables and disallowables that evolve through any culture.

It would be of value to an Ouraboratorium to **generate and coordinate cultural artifacts** (ranging from a work of art to a complex project) that would register change, remain open to continuous renegotiations, act as agents of double-description, aid the group via triangulations (group-problem-artifact), reflect on its own practice, and evolve as the problem-solving process unfolds.

**To develop the Ouraboratorium into a full fledged design methodology, planning or modeling groups of this sort deserve further attention, practice, application, and support.**

**Note**
The word **Ouraboratorium** derives from “ouroboros,” a snake that bites its own tail, ancient symbol of self-reference and reflexivity, now widely used in cybernetics, and “laboratorium,” Latin for a space for scientific experimentation and research.

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Everything is Changing: A New (Inter)Face for Design

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ABSTRACT
With change occurring in most every aspect of our lives, the field of graphic design is undergoing change as well. Building on a foundation of visual communication, graphic designers possess a set of skills, knowledge, and a point of view that are unique in the (relatively new) field of interface/interaction design. They offer a human-centered approach, a rich complement to the machine-centered focus of engineers and system designers. This paper argues for greater participation from designers in the important work of bringing technology to people.

Keywords
Change, graphic design, interaction, interface, process

INTRODUCTION
The medium, or process, of our time — electric technology — is reshaping and restructuring patterns of social interdependence and every aspect of our personal life. It is forcing us to reconsider and reevaluate practically every thought, every action, and every institution formerly taken for granted. Everything is changing — you, your family, your neighborhood, your education, your job, your government, your relation to "the others." And they're changing dramatically.

Marshall McLuhan
The Medium is the Massage
1967

Such startling advances and cost reductions are occurring in microelectronics that we believe future systems will not be characterized by their memory size or processing speed. Instead, the human interface will become the major measure, calibrated in very subjective units, so sensory and personalized that it will be evaluated by feelings and perceptions. Is it easy to use? Does it feel good? Is it pleasurable? Such quality is no longer a luxury but a requirement.

Nicholas Negroponte
Spatial Data-Management
1979

Much has happened over the past twenty-five years to support McLuhan's observation in the mid-sixties and Negroponte's prediction in the late seventies. Besides the technological leaps that continue to alter the way we work, play, and interact with each other, a field of work and study emerged in those years. Known alternately as human-computer interaction (HCI) and computer-human interface (CHI), this field of design addresses means and methods of interaction between people and computing systems. There are national and international organizations, special interest groups, R&D divisions, and programs of study devoted to this field, which, when viewed with some perspective, is still in its infancy. The national organization, CHI, for example, is a mere twelve years old.

If this indeed is a design activity, then why is human-computer interface and interaction design still such a stranger to the graphic design community? While I pose this question to graphic designers, it should be posed to industrial designers as well. At national and international conferences devoted to interface and interaction design, the majority of attendees represent the computer science and psychology communities, with their interests in systems design, object-oriented programming, interface design management, and user testing, to name a few areas. In contrast, there are but a handful of visual designers in attendance — 2% at best — with their expertise in communication design, information systems, and graphic design. They tend to have difficulty relating to papers and presentations with topics covering eye movement-based interaction techniques, GOMS analysis, and the design space of input devices. There is talk about design, but the vocabulary is different, the writing dense, and on the whole, there is little in common between systems designers and graphic designers.

I have two answers to the question above. First, interface design is still not part of a graphic designer's education. Second, there are very few role models of designers doing HCI work, and these few don't have many opportunities to share their experiences with the larger design community. True, there are a few notable exceptions to these two points, but the current state of graphic design education and practice is still dominated by print-related work. Designing information for display on a computer screen, let alone a sequence of interactive screens, is still not regarded as graphic design work by the majority of professional designers.

Consider what we call ourselves: graphic designers. The very term graphic suggests the printing process, ink on paper, static, and two-dimensional. The term communication, on the other hand, refers to both the act and the product, and, therefore, encompasses any medium employed in conveying information. This broader definition should now include print, packaging, environmental signage, film, video, computer inter-
faces, and interactive media. Communication is at the heart of designing for these media, and communication continues to be the backbone of a graphic designer's education. When connected to product development, this broader definition may include the design of the objects themselves and their machine-control surfaces. The world is changing much too rapidly for us to ignore the need for new and innovative methods of communicating with one another. With technology reshaping communication, we now find interactive television and personal digital assistants (PDAs) joining book design and identity programs in the arena of communication design work.

INTERACTION = COMMUNICATION

So, why should communication designers be involved in human-computer interaction design? Simply put, because interaction design is communication design. Every interaction design project has a communication component to it. The words interface and interaction suggest communication between persons or between a person and a product. The words tend to be used interchangeably, but a distinction can be made. In current use, the term interface refers quite specifically to the visual display of information on a computer's monitor, while interaction refers to the manner and mode of communication between a person and a product. So, we can refer to the Macintosh interface, but one's interaction with a fax machine. For too long, there was an emphasis on technology driving the product's design, on the computer component of the human-computer equation. For most of us, this attitude has been evident for at least a decade with household electronic devices, like digital watches, answering machines, and the ubiquitous VCR. IDEO's Bill Moggeridge describes this design attitude as, "kind to the chip, cruel to the user" (Moggeridge, 1993). We all have personal adventures to share regarding poorly labeled buttons or incomprehensible remote controls, don't we?

In the early 1980s, as computing for the technically literate few gave way to personal computing for the working masses, systems engineers — computer programmers, in overly simplified terms — were still responsible for defining and creating the entire interface: the system architecture, the programming, how data was to appear on the screen, and how the user would interact (communicate) with the system. While intentions were noble, the results, on the whole, were problematic. Expecting users to memorize command lines and to read screen after screen of reversed type was the norm for many years. Assumptions were made that the user population resembled programmers who sat at computers writing code eight to ten hours a day. Terry Winograd's closing address at CHI '90 (the annual Computer-Human Interaction conference) built on this theme when he said, "Computer science departments are not generally noted for respecting much of anything outside of their disciplinary boundaries . . . Consideration of human factors, social impacts, and design methodologies have appeared as tangential add-ons to the study of 'real computer science.' People and organizations are often viewed as an unfortunately unpredictable and messy part of the technological environment" (Winograd, 1990). Strong words, particularly coming from a senior spokesperson of Computer Science at Stanford.

In the late '70s and early '80s, the emergence of graphical user interfaces (GUIs) with the Xerox Star, the Apple Lisa, and the Macintosh changed the "look (literally) and feel" of computer interfaces. Communicating with a computer through icons, windows, and a mouse made it easier and more natural for many to use. For the designer of a computer interface, new issues had to be considered beyond the structuring and coding of the program. Issues of communicating with symbols, color, text, windows, scroll bars, cursors, and simple animation were introduced. Issues of cognitive processing, mental mapping, and human perception and performance were raised. Fundamentally, graphic user interfaces demanded a focus on how people interacted with the system, on their expectations of the system, and on the tasks to be done; in short, on the user's experience with the computer. The focus had finally shifted to the human component of the human-computer equation.

MULTIDISCIPLINARY COLLABORATIVE DESIGN

With this new focus on the human experience, often called human-centered or user-centered design, comes the realization that designing the system's interface is a complex task requiring the input of more than one expertise. It calls for a development team that is able to address the wide set of issues raised in the normal course of designing a user interface. No one individual has the experience or the knowledge to answer all the questions that arise. The solution is in multidisciplinary collaborative work, with experts from various fields participating in the conception and design of how a person and a computing device might communicate with each other, in the context of software that supports work or play.

Critical to the success of any venture like this, the full team needs to work together from the start of the project, charting its course, defining the problem, and setting goals. Bringing
in, say, a visual interface designer towards the end of an interface project to add “window dressing” (pun intended) has proven to be a mistake — too little, too late in the process. The job of managing a diverse team like this — with its collection of backgrounds, agendas, and jargon — is a serious challenge. Finding a team leader who knows when and how to push, to hold back, and to be pragmatic is indeed a daunting task; in fact, it may be the most difficult job on the team.

The content, context, and complexity of an interface project determine the makeup of a team. Areas of expertise represented on a typical team may include systems design, cognitive psychology, cultural anthropology, information systems, communication design, writing, animation, and product design. I would add filmmaking, dance, and theater because narrative, movement, and drama are key to creating engaging and flowing interfaces. Apple Computer’s S. Joy Mountford has been a strong advocate for including one or two individuals who represent the target audience as part of the development team and not simply as test subjects brought in toward the end of the project (Mountford, 1992). This eliminates guessing about audience needs, preferences, and responses, as the project progresses. “Get to know your user,” she urges.

As communication designers, we do consider our users — our client and our audience — with every job we design. We place them in context as we take into account who they are, what visual/verbal/cultural languages they subscribe to, and what the client’s intent and audience’s expectations are. These human factors guide us as we engage in the design process. Graphic designers may not currently use these precise terms to describe these factors, but that’s what they are. I mention them to distinguish human factors from formal factors: the designer’s formal, aesthetic language. Last year’s ACD Journal devoted an entire issue to the “New Human Factors” — physiological, cognitive, social, and cultural — that we should be considering holistically, with the goal of more humane products for our audiences (ACD Journal, 1993). It is well worth reading.

THE SOCIAL SCIENCES AND INTERACTION DESIGN

The social sciences have much to teach us about our users. Ethnographers, those individuals whose business it is to observe and record human behavior, are proving to be of great value to interface design efforts. They know how to unobtrusively observe a community of individuals at work in their normal environment. Usually with the aid of video cameras and sound equipment, they capture hours of data and know what to look for as they “read” these tapes. Patterns of behavior emerge; patterns of speech, of gesture, of traffic are searched for and noted. By watching, for example, a group of accountants in the context of their work spaces, we learn a great deal about how they do their work, where it is done, and with whom. Not surprisingly, we discover that work is done not just at one’s desk on one’s computer, but also while at the coffee machine or the copier, walking down the hall on the way to a meeting, or at a brief conversation over a break. These observations inform discussions about interface design by placing them in the context of everyday work. This is quite different from the user testing that human factors experts, mostly psychologists, engage in. The primary difference is that the ethnographer objectively observes people in situ, while the psychologist removes an individual from the work site and engages in user testing at some isolated or remote location. Both methods yield valuable data when done at the proper stages in the design process. The ethnographic study should take place as one of the first steps in the process, in order to inform early discussions about the audience, while user testing should take place later in the process when a rough prototype is available for evaluation. Knowing when to use each method is key.

WHY US?

What can communication designers bring to interface design work? Far too often, designers shy away from this kind of work with the excuse that they have nothing to contribute, not having been trained in this field. While it is true that they have not been trained in this field, I want to point out that designers have a methodology, a set of skills, and a focus on human communication that are relevant to the practice of interface design.

Communication designers are educated in the areas of communication planning and design, visual/verbal communication theory and practice, typography and its impact on legibility and readability, composition of elements on a format, and design iteration and evaluation. We apply this expertise every day to the design of print, exhibition, or signage projects. We know how to give a message impact by expertly juxtaposing the right words and the right pictures. We know about nuance in typefaces, color, and composition. We know about sequencing text and graphics in a magazine or book, working with grids for consistency, yet knowing when to break the grid for surprise and change of rhythm. We give visual voice to our client’s message, guided by intent, context, and an understanding of audience expectations. It is precisely this expertise in purposeful and goal-directed human communication that is needed in interface design.

Methodology

While we may not agree on a single model of the design process, there is general agreement that it includes aspects of planning, analysis, invention, and evaluation. Curiously, the larger design community rarely reflects on what we do, how we do it, and why. As a result, we lack consensus on methodology, not to mention a vocabulary for discussing process and

anthropology, n.
The scientific study of the origin, the behavior, and the physical, social, and cultural development of human beings.

ethnology, n.
The science that analyzes and compares human cultures, as in social structure, language, religion, and technology; cultural anthropology.
the resulting artifacts. Nonetheless, let me discuss a few issues relevant to both communication and interface design.

Exploration
Exploring alternatives begins the early phase of invention for a designer. This involves pushing the limits of invention while constantly asking the question, "How else might I solve this problem?" Translated to interface work, a designer might ask, "Why do buttons have to look like hardware controls? How else might I represent them? With semantically-rich form? A scanned image? An animated icon?" Searching for new forms and innovative solutions can only enliven the visual quality of interfaces that are currently held captive by desktop metaphors and windowing systems. New software applications are more complex than they were ten years ago, yet, in many cases, their interfaces haven't matured much. Communities of users have specific needs that are not fully met with generic interfaces. This is why designers, with their visual expertise and concern for audience, are perfect for the task of inventing new interface environments and paradigms. Questions relating to the intent, voice, and context of the message are relevant here, as they have always been with print work.

Visualization
Designers are expert at visualizing ideas. During a team discussion, a designer may be busy sketching, giving rough form to notions, to hand gestures, to ideas thrown out and built upon. Sketching "thumbnails" (small, quick drawings) is part of any designer's skillbase and these shorthand visual notations can later be discussed, amplified, and developed further. In fact, the use of sketches, and not final renderings, can help to focus the team's attention on the questions at hand, instead of distracting them with details found in highly rendered iterations (Wong, 1992). Quick sketches may even serve as early prototypes, which allow for early evaluation and more rapid iterations.

Evaluation
Designers work in iterative cycles, focused on a problem statement that becomes the metric against which ideas are evaluated. A common method of evaluation often takes place at informal critiques, with sketches on paper pinned up on a wall, and participants discussing what's working and what's not, while comparing and contrasting one sketch with another. This activity is second-nature to any designer, having participated in endless critiques at school. But to non-designers, a critique is often a new and revealing experience. Valuable insight is gained when discussing the pros and cons of several ideas in one setting. This activity, by the way, is impossible to do on-line, as has been suggested by my technical colleagues. You might view one or two "sketches" on a monitor, then have to commit them to memory while you open up the next files. This becomes tedious and unproductive, given the lack of comparison and contrast across a number of sketches. A computer monitor is not a wall. Additionally, the human dynamic that is very much a part of a critique — the dialogue, the body language — just cannot be reproduced or captured on-line.

The Rhetoric of Communication
With our focus on human communication, we can take any piece of communication design and ask the question: what is it's intent? Three rhetorical purposes offer us a way of categorizing our work in relation to client, audience, and intent as we answer that question. There is work that teaches or informs, such as schedules, textbooks, maps, and catalogs. There is work that moves the reader to action, such as a call for participation, a plea for donations, or a concert poster. And there is work that pleases or entertains, such as a paper promotion piece, or a series of television commercials for athletic shoes. In most cases, we find that an expert combination of two, or even three, of these purposes is what produces effective and memorable communication.

Similarly, in interface design work, we can categorize applications according to intent. At one end of the spectrum, you find interfaces that inform, as they support specific tasks, such as in business, medical, and engineering applications. Then there are museum information kiosks that both inform and entertain; or educational software modules that teach and may even move one to action. At the other end of the spectrum are adventure or mystery games whose purpose is pure pleasure. Similar to communication design work, the combination of two or three rhetorical purposes, with varying degrees of emphasis, begins to define appropriate and effective solutions. Viewing any of these software or hardware applications as having a communication component begins to invite a designer's participation.

WHAT NEXT?
If designers wish to participate in interface interaction work, then there are challenges ahead. We need to widen our view of communication design to include new arenas like software design, interactive programs, and human-machine interaction. We need to forge links with key disciplines already involved in aspects of this work — disciplines like computer science, cognitive psychology, engineering, human factors, and the social sciences. We need to familiarize ourselves with emerging platforms for information/entertainment delivery, such as interactive television, CD-ROM technology, and wire-less devices. We need to become technology literate — not simply computer literate — by keeping up with the literature on new developments, but not forgetting the critical commentary on its social and cultural impact. We will see many new interactive products becoming smaller and more personal, with input modes to include speech, handwriting, and gesture. Be prepared, though, for there is much hype to sift through. Finally, we need to appreciate the fact that new product development is, in fact, closely tied to interface interaction design: why separate the design of the object from its interaction? To the user, the interface is the product. Keep in mind, the organization and visual display of data or information will con-
continue to be a major component in any of these applications, as it has always been with print work, only now, we will have motion and sound, along with text and pictures, to design and design with. The implications for the future of design education and practice haven’t yet been fully grasped.

The two points I raised at the beginning of this paper need our collective attention. First, more educational design programs need to begin introducing an HCI involvement, if not a focus. Graduate programs may be best suited for this focus, with a balance of theoretical investigation and applied project work. Second, those designers involved in interface/interaction design work should be invited by both educational and professional organizations to share their work and expertise.

The design communities — both graphic and industrial — need to make it their responsibility to be better informed. The American Center for Design has made a commitment to this field with occasional journal articles over the past few years and a well-attended conference last fall devoted to multimedia in graphic and industrial design. There is still much work to be done and I suggest we be a part of it.

Whatever we call ourselves — communication designers, graphic designers, visual communicators — we have valuable contributions to make to human-computer interface and human-machine interaction design work. Not unlike paper-based communication, we should be advocates for clear thinking, complex and rich information display, and elegance of form. We can bring a human-centered focus to a team’s discussions of the user’s experience with a computing device or system. How does our solution best help the user concentrate on the task at hand and not on the system itself? Is our interface forgiving of human error? When dealing with the interactive presentation of information, do we clarify, simplify, and enrich the process of interaction?

“There is nothing like dream to create the future,” wrote Victor Hugo. It will be dreamers who shape new products, with new interfaces and interactions, for new generations of users. We need dreamers to humanize the highly technical future we are creating today, and to add some enjoyment to the experience of developing and using these products. As technology continues to drive our evolution toward McLuhan’s vision of a connected global village (McLuhan, 1967), we have a responsibility to participate in shaping that vision. We can’t afford not to.

REFLECTING ON FIVE YEARS OF TEACHING HCI DESIGN

Introducing interface design into a Communication Design program made sense to us in the Design Department at Carnegie Mellon; it was a natural extension of our information design-based curriculum. It was also important that the field of communication design help define the practice of HCI and join other fields in this task. Five years ago, ours was the sole interface design course taught on campus. In the spring ’94 semester, there are a dozen course offerings representing seven departments, indicating widespread interest and participation across disciplines.

Our first interface design course was offered only to graphic design seniors, one of several senior project options. Eight students worked in two-person teams or alone on an NCR-sponsored project focused on designing the interface for self-service terminals. Areas of exploration included an Encyclopedia searching tool for high school students, a real estate browser, and an on-line florist. The next year we offered the course, it was open not only to designers, but to students from across campus. Sixteen students participated — half from Design, the other half from departments like Professional Writing, Computer Science, and Information Systems. Teams of three or four students represented the multidisciplinary collaborative model we wanted to try out. The mix of disciplines provided the teams with differing perspectives on the problem to be solved and a more holistic approach to the solution. As expected, team dynamics were at times a problem — an accurate reflection of the challenges posed to any multidisciplinary team. But having to resolve conflicts, and to respect and build on each other’s differences were important lessons learned. Teamwork is proving to be an important skill for a designer, one we should be teaching and fostering throughout a student’s career.

Subsequent projects for NCR and Apple have all promoted multidisciplinary team work, and, not unlike the process involved in a print-related piece, we stress defining the project up front, understanding the client and audience, sketching and prototyping ideas quickly, evaluating ideas throughout this iterative process, and documenting the entire process. The resulting report to the client serves two functions. It is the final report, tracing the entire process with documentation of concept sketches, visual and verbal notations, user testing plans and results, and principles that guided the final solution. It also offers the participants — students, faculty, and client — a forum for reflection upon the project just completed. As a piece where planning, writing, and visualizing all come together seamlessly, it is yet one more manifestation of the power of collaboration.

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Heuristics as Common Language for HCI Design and Evaluation

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Human Interface Design Center
Apple Computer, Inc.

ABSTRACT
A simple fundamental problem in the design of human-computer interfaces (HCI) is the lack of a practical common language of design. HCI design involves a variety of disciplines, each of which has its own argot. Communication is critical among members of a design team, yet there is no shared customary language. This paper introduces terms and examples that can serve as a foundation for common language between HCI designers, and reports on experiences using that language in 127 student projects to evaluate software products.

Keywords
Heuristics, GUI, design, evaluation, usability

INTRODUCTION
The discipline of human-computer interaction focuses on communication between people, computers, and tasks. As a part of industrial design in general, the design of computer interfaces is intent on making software that is easy to use. Defining what contributes to ease of use is an ongoing debate. Many sets of general principles for good design, or design heuristics, have been proposed over the last decade. The effort to set forth usable design guidelines for the development of interfaces has evolved from early general homilies of a practical nature, to precisely articulated definitions of the properties of well-designed artifacts. One of the most recent catalogs of heuristics is an interesting collection of what the authors term thinking tools (Dix et al., 1993) — three basic categories of design heuristics comprising more than twenty specific terms.

As a practical matter, how can this collection of terms be employed? Dix et al. define no praxis of design; they do not proceduralize the application of these terms, neither in design, nor in evaluation. However, the terms themselves present a good beginning for the development of a context-dependent language of design that can affect the well-known issue of communication between design team members. Such common language serves to structure communication among designers, and particularly the interdisciplinary conversation between interaction designers, visual designers, and software engineers. This paper presents Dix et al.’s terms as a foundation for common language, and describes the use of that language in both the design and the evaluation of human-computer interfaces.

HEURISTICS FOR USABILITY
Dix et al. propose that there are two approaches to creating usable systems; one is by following the example of systems that are generally agreed to be well-designed, and the other is by following a more or less abstract set of principles (Dix et al., 1993). They offer a set of fourteen principles with related sub-principles and definitions for each, divided into three major categories: learnability, flexibility, and robustness. Tables 1-3 below list these heuristics as they are found in the Dix et al. text. This is intended to be an easily extendible (and not conclusive) catalogue of general principles which can be applied to the design of an interactive system in order to promote its usability. While their taxonomic structure is arguable (many of the principles are deeply inter-related), the content of this overall structure provides an excellent language foundation for design.

The distinction between this effort and other efforts to catalog design principles is the precision of naming. Each principle has a definition; each related principle is somewhat less general and also has its own definition. Upon inspection, all of the principles convey properties which the authors believe are necessary to acknowledge in interactive systems. Some of the definitions indicate that a particular principle has a necessary value and is thus normative (e.g., systems should be predictable and consistent), while others require the designer to assign a value (where is the dialog initiative, with the system or the user, and where should it be?) and are thus contingent. In this respect, all of the principles are not general prescriptive usability principles — they must be viewed in the context of a particular system design.

Most of the work done on heuristics is in the area of evaluation, not design itself. Although there are many methods to evaluate human interface designs, the traditional method is usability testing in a laboratory setting. Other methods include cognitive walkthroughs and GOMS analysis. Jakob Nielsen developed his own set of heuristics and heuristic evaluation as a "discount usability method" to decrease the sometimes considerable costs of testing — meaning that it is generally a more expedient way to test a product design than other more time-consuming or expensive methods. Heuristic evaluation requires evaluators to inspect a product (in vir-

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Table 1. Summary of principles affecting learnability.

<table>
<thead>
<tr>
<th>Principle</th>
<th>Definition</th>
<th>Related principles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predictability</td>
<td>Support for the user to determine the effect of future action based on past interaction history.</td>
<td>Operation visibility</td>
</tr>
<tr>
<td>Synthesizability</td>
<td>Support for the user to assess the effect of past operations on the current state.</td>
<td>Immediate/Eventual honesty</td>
</tr>
<tr>
<td>Familiarity</td>
<td>The extent to which a user's knowledge and experience in other real-world or computer-based domains can be applied when interacting with a new system.</td>
<td>Guessability, Affordance</td>
</tr>
<tr>
<td>Generalizability</td>
<td>Support for the user to extend knowledge of specific interaction within and across applications to other similar situations.</td>
<td></td>
</tr>
<tr>
<td>Consistency</td>
<td>Likeness in input/output behavior arising from similar situations or similar task objectives.</td>
<td></td>
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</tbody>
</table>

Table 2. Summary of principles affecting flexibility.

<table>
<thead>
<tr>
<th>Principle</th>
<th>Definition</th>
<th>Related principles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dialogue initiative</td>
<td>Allowing the user freedom from artificial constraints on the input dialogue imposed by the system.</td>
<td>System/User pre-emptiveness</td>
</tr>
<tr>
<td>Multi-threading</td>
<td>Ability of the system to support user interaction pertaining to more than one task at a time.</td>
<td>Concurrent vs. Interleaving, Multi-modality</td>
</tr>
<tr>
<td>Task migratability</td>
<td>The ability to pass control for the execution of a given task so that it becomes either internalized by user or system or shared between them.</td>
<td></td>
</tr>
<tr>
<td>Substitutivity</td>
<td>Allowing equivalent values of input and output to be arbitrarily substituted for each other.</td>
<td>Representation multiplicity, Equal opportunity</td>
</tr>
<tr>
<td>Customizability</td>
<td>Modifiability of the user interface by the user of the system.</td>
<td>Adaptivity, Adaptability</td>
</tr>
</tbody>
</table>

Table 3. Summary of principles affecting robustness.

<table>
<thead>
<tr>
<th>Principle</th>
<th>Definition</th>
<th>Related principles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observability</td>
<td>Ability of the user to evaluate the internal state of the system from its perceivable representation.</td>
<td>Browsability, Static/Dynamic defaults, Reachability, Persistence, Operation visibility</td>
</tr>
<tr>
<td>Recoverability</td>
<td>Ability of the user to take corrective action once an error has been recognized.</td>
<td>Reachability, Forward/Backward recovery, Commensurate effort</td>
</tr>
<tr>
<td>Responsiveness</td>
<td>How the user perceives the rate of communication with the system.</td>
<td>Stability</td>
</tr>
<tr>
<td>Task conformance</td>
<td>The degree to which the system services support all of the tasks the user wishes to perform and in the way that the user understands them.</td>
<td>Task completeness, Task adequacy</td>
</tr>
</tbody>
</table>

The principles used in heuristic evaluation are general rules that describe common properties of usable interfaces. Those rules can be guidelines written at the general level (to be followed by all systems), at the category-specific level (to be followed by all systems falling within a certain category), and at the product-specific level (to be followed by a specific product). Nielsen allows, however, that "most people probably perform some kind of heuristic evaluation on the basis — likely due to the fact that the evaluators have experience in design, guidelines against which to evaluate, and can move quickly through an interface inspection with minimal prescribed task constraints.
of their own intuition and common sense instead" (Nielsen, 1993). Many sets of heuristics exist. Nielsen conducted a factor analysis of the explanations of usability problems derived from comparing seven different published sets of usability heuristics to a database of existing usability problems. From this, he determined which heuristics best explain actual usability problems, and revised his list of general usability heuristics (Nielsen, 1994); compare the two following tables. These heuristics, he claims, seem to be excellent for explaining previously found usability problems; Nielsen makes no claims, however, for the extent to which they are also good for finding new problems. Two significant problems arise in applying any of the seven sets of heuristics: 1) evaluators find it difficult to limit their evaluation to the sets of heuristics given them to use, since they have extensive knowledge and experience in the use of other heuristics or their own intuition; and 2) the evaluators' views are necessarily subjective. Further, these sets of principles were not compiled with the same intended purpose.

<table>
<thead>
<tr>
<th>Table 4. Nielsen's Heuristics, ca 1993</th>
</tr>
</thead>
<tbody>
<tr>
<td>simple and natural dialogue</td>
</tr>
<tr>
<td>speak the user's language</td>
</tr>
<tr>
<td>minimize the user's memory load</td>
</tr>
<tr>
<td>consistency</td>
</tr>
<tr>
<td>feedback</td>
</tr>
<tr>
<td>clearly marked exits</td>
</tr>
<tr>
<td>shortcuts</td>
</tr>
<tr>
<td>good error messages</td>
</tr>
<tr>
<td>prevent errors</td>
</tr>
<tr>
<td>help and documentation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 5. Nielsen's Heuristics, ca 1994</th>
</tr>
</thead>
<tbody>
<tr>
<td>visibility of system status</td>
</tr>
<tr>
<td>match between system and the real world</td>
</tr>
<tr>
<td>user control and freedom</td>
</tr>
<tr>
<td>consistency and standards</td>
</tr>
<tr>
<td>error prevention</td>
</tr>
<tr>
<td>recognition rather than recall</td>
</tr>
<tr>
<td>flexibility and efficiency of use</td>
</tr>
<tr>
<td>aesthetic and minimalist design</td>
</tr>
<tr>
<td>helping users recognize, diagnose, and recover from errors</td>
</tr>
</tbody>
</table>

A distinct disadvantage of Nielsen's heuristics, and the others he evaluated, are that many of them are phrases that relate to complex sets of design issues, and as such are not specific, clearly articulated principles. This is the advantage of the Dix et al. work: the heuristics are distinct and fully described. As teaching tools, the Dix catalogue is far superior. This appears to be supported in the results of student tests detailed below.

STUDENT PRODUCT EVALUATIONS
Over a period of three years, the author taught a condensed six-week Human Factors in Systems Design course eight times to 106 students at the University of San Francisco. One of the course requirements that remained consistent throughout this period was the requirement for students to perform heuristic evaluations on the interface of a software product of their choice. Evaluation Set 1 was used for the first three sections of the course; these heuristics are based on (Laurel, 1990). Evaluation Set 2 was used for the remaining five sections of the course; these heuristics are based on (Dix et al., 1993).

There were a total of 127 evaluations performed. All students were exposed to sample reviews via videotapes of experimental systems or through live software demonstration. Grades for each evaluation have been normalized to a 100 point scale (some were graded on a 25 point scale while others were graded on a 20 point scale). All students were graded on their ability to manipulate the evaluation concepts. The grades were significantly higher using Evaluation Set 2 than using Evaluation Set 1; the average grade of students using Evaluation Set 1 was 81 points, compared to 88 points using Evaluation Set 2. The median grades were also higher for Evaluation Set 2, indicating fewer low scores lowering the average. There are some variations to be considered in analyzing this difference. The sets of heuristics were derived from two different texts. Students using Evaluation Set 1 were allowed to do as many or as few evaluations as they liked to accumulate points for course credit. Students using Evaluation Set 2 were all required to do a single evaluation. Students had some difficulties performing interface evaluations; many at first confused feature reviews with interface evaluations. The primary difficulty students had were in coming to terms with the lists of heuristics given them. This is in part due to the unfamiliarity of the material; however, the majority of difficulty was in deciding what each of the heuristics meant. In the case of Evaluation Set 2, students reported that after learning to use the heuristics, they acquired the ability to articulate what they intuitively felt about an interface. Several students were intrigued with the process of using these heuristics and the heuristic evaluation process. They reported using them in their workplace to assist in making purchasing decisions for software, and for evaluating development projects in which they participated.

EVALUATION PROCESS DEVELOPMENTS
Students were not only asked to learn the heuristics and apply them; in the case of the students using the Dix et al. set of heuristics, students were asked to think about the contextualized use of heuristics. When asked which heuristics were the most important to apply, students generally defaulted to the main categories of learnability, flexibility, and robustness. However, when prompted to think about different kinds of systems, students developed the following taxonomy of system types: exploration, learning, games, communication, production, and systems administration. Table 6 reports on one group's taxonomy and the heuristics they felt were most important to each.
<table>
<thead>
<tr>
<th>Evaluation Set 1</th>
<th>Evaluation Set 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>58 reviews conducted</td>
<td>69 reviews conducted</td>
</tr>
<tr>
<td>avg. grade 81</td>
<td>avg. grade 88</td>
</tr>
<tr>
<td>med. grade 87</td>
<td>med. grade 93</td>
</tr>
<tr>
<td>layout (consistent placement of elements, consistent appearance/behavior of elements, appropriately focus user's attention - distinctions between relevant screen parts, elimination of visual competition)</td>
<td>predictability</td>
</tr>
<tr>
<td>use of color and sound</td>
<td>* predictability visibility</td>
</tr>
<tr>
<td>typography</td>
<td>synthesizability</td>
</tr>
<tr>
<td>use of graphics, symbols, icons - do they make sense?</td>
<td>* guessability</td>
</tr>
<tr>
<td>navigation - number of steps to get basic information, ability to find your way around vs. getting lost, ability to cancel operations</td>
<td>* affordances</td>
</tr>
<tr>
<td>ease of use, user friendly, intuitive unambiguous; ease of learning</td>
<td>generalizability</td>
</tr>
<tr>
<td>consistency of common functions (help, print)</td>
<td>consistency</td>
</tr>
<tr>
<td>on-line help facilities follow principles</td>
<td>dialogue initiative</td>
</tr>
<tr>
<td>design for error; forgiveness, politeness, recoverability</td>
<td>multi-threading</td>
</tr>
<tr>
<td>customizability</td>
<td>* concurrent vs. interleaving</td>
</tr>
<tr>
<td>appropriate functionality for user's task (reduces perceived complexity)</td>
<td>* multi-modality</td>
</tr>
<tr>
<td>direct manipulation</td>
<td>task migratability</td>
</tr>
<tr>
<td>feedback (sound for error, for status; visual)</td>
<td>substitutivity</td>
</tr>
<tr>
<td>feedback (sound for error, for status; visual)</td>
<td>* representation multiplicity</td>
</tr>
<tr>
<td>acceptable performance, response time</td>
<td>* equal opportunity</td>
</tr>
<tr>
<td>continuity</td>
<td>customizability</td>
</tr>
<tr>
<td>increases competence of users</td>
<td>* adaptivity</td>
</tr>
<tr>
<td>use of animation</td>
<td>* adaptability</td>
</tr>
<tr>
<td>seamlessness</td>
<td>observability</td>
</tr>
<tr>
<td>transparency</td>
<td>* browsability</td>
</tr>
<tr>
<td>redundancy</td>
<td>static/dynamic defaults</td>
</tr>
<tr>
<td>creativity</td>
<td>* reachability</td>
</tr>
<tr>
<td>use of metaphor (consistent, which metaphor, how extensively used)</td>
<td>* persistence</td>
</tr>
<tr>
<td>defaults (&quot;mimics intelligence&quot;)</td>
<td>recoverability</td>
</tr>
<tr>
<td>quality of documentation</td>
<td>* forward/backward recovery</td>
</tr>
<tr>
<td></td>
<td>commensurate effort</td>
</tr>
<tr>
<td></td>
<td>responsiveness</td>
</tr>
<tr>
<td></td>
<td>* stability</td>
</tr>
<tr>
<td></td>
<td>task conformance</td>
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<tr>
<td></td>
<td>task completeness</td>
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<tr>
<td></td>
<td>task adequacy</td>
</tr>
<tr>
<td></td>
<td>seductiveness</td>
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<tr>
<td></td>
<td>addictiveness</td>
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<td></td>
<td>cultural sensitivity</td>
</tr>
<tr>
<td></td>
<td>aesthetic appeal</td>
</tr>
</tbody>
</table>

**Table 6. Students' conception of system taxonomy**
What is important to gain from this exercise is not the particulars of which heuristics students placed in which category, nor in the particular categories noted. The salient point is that students were able to discriminate between different system objectives, and to view heuristics for design (as well as evaluation) not as absolutes, but as context-dependent guidelines. An excellent example is in the application of heuristics to software games. Students felt that games have different inherent properties than the other system types, and that they have necessarily different objectives for the user experience. These students felt that a game that is not seductive is not interesting; if it’s not interesting, then it won’t be played, whether or not it is highly responsive and easy to learn. If it is not designed with these guidelines in mind, then it is not going to satisfy users. Consequently, the choice of heuristics must be determined at the very earliest stages of design. Should design direction change and other objectives be attempted, the rationale for the change and the new design heuristics should be documented so that the developed artifact can ultimately be tested against the same heuristics.

HEURISTICS IN PRACTICE
In a 1994 paper on usability in practice at Apple Computer, Gomoll and Wong stated that several usability specialists are cycled through the same project during different phases, in order to see a product through fresh eyes and filter out researcher biases (Gomoll & Wong, 1994). However, this no longer applies; at the present, we have more usability specialists and a more stable arrangement for primary user studies. Apple Computer’s Human Interface Design Center performs usability testing for product evaluation as expediently as possible. The professionalism and expertise of the individuals chartered to do testing serves to filter bias of two types: 1) methodology (whether data is tainted by sampling or type of questions); 2) more importantly, conceptualization of the problem at hand. The preferred process is to have different people with usability expertise consult on the problem to be tested before implementing. Reformulating the problem can change the methods used. At Apple Computer, a significant aspect of the Macintosh Human Interface Guidelines is design philosophy. For some projects we don’t have the time to “bring someone up to speed” with the guidelines; we do have an expectation that people know and understand the HCI issues and philosophy addressed in the guidelines book. We prefer usability specialists who are able to manipulate the concepts and have experience applying them (Wong, 1996).

What this means, in effect, is that the philosophy of design is the most important guideline to understand. This often results in interpretive differences. Two strategies can help to resolve those differences: the use of common language for general communication, and the use of design exercises in selecting and prioritizing a small set of heuristics appropriate to the specific context of each project.

How can the Dix et al. heuristics be used in industrial settings? It requires an educational effort. The challenge to educators in software development and human-computer interaction is to base design and evaluation skills in the manipulation of a common language of heuristics. While Dix et al. readily admit that their list is not conclusive, and represents more of a “living catalog,” it has the attractiveness of anchoring language with clear interpretation, and flexible applications. This is not to say that terminology should be rigid and uncompromising. Rather, generally accepted terms and meanings will help communication.

RECOMMENDATIONS TO INDUSTRY AND ACADEMIA
Institutions engaged in teaching the design of artifacts, especially software interfaces, should strive to introduce high-quality, well-thought-out design principles. Extending the Dix et al. catalogue is a good beginning. Adding HCI design principle discussions to the problem definition stage of product concept development, and referring back to those principles frequently, should be a part of any product process, in the abstract (e.g., software development life cycle) as well as the concrete (specific companies’ product process requirements). Industrial design and human-computer interface design groups should maintain a philosophy of design document and a glossary of descriptive terms as a supplement to any other level of general guidelines or checklists. And finally, practitioners must participate; a design language is of no use if it is not shared.

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Society, Sensibility, and the Design of Tools for Collaboration

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UARTS, Philadelphia / University of California, Santa Cruz

Elizabeth Dykstra-Erickson
Human Interface Design Center
Apple Computer, Inc.

ABSTRACT
This paper is a conversation from two perspectives: ART and TECHNOLOGY. We examine complementary paths toward design, with the intent of improving the design of instruments of collaboration. We set the stage for our discussion by examining the failure of objectivism and the constructivist response. We then explore socially coded sensibility and the design of tools for collaboration as media which enhance communication within that socially coded sensibility. We offer some insights into how the process of design must inform, create, and sustain social coherence. We conclude with an agenda for research and education in collaborative technology.

Keywords
Technology, collaboration, art, constructivism, sensibility, design

INTRODUCTION
It is essential to understand the social phenomenon of collaboration in order to create tools to support it. This paper suggests two complementary paths of design process. The first concerns the artist who creates an artifact, in an ongoing process, that registers decisions in a context that is larger than could be comprehended by the creator in a definitive way at any time during its production. The operating environment of the artist — the sensibility — unifies conscious and unconscious process. The second path is that of the technologist who designs collaborative support systems. The operating environment of the technologist is one of rules, guidelines, and techniques within a context of validation, usefulness, and purpose. We propose that the design of collaborative tools is less an exercise in designing objects than in designing facilitators to social events — tools that promote communication between collaborators, and development, by the users, of social patterns: a socially coded sensibility. Given this focus, we propose that technology that serves to support collaboration should support social needs, and understanding those needs is an important item on the agenda for future research and design education.

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COLLABORATION AS AN ALTERNATIVE TO COMPREHENSIVE INFORMATION
Complexity and abundance of information is too great for any one to absorb; it is uncontainable. From an objectivist perspective, the burgeoning proliferation of information is filling the world up — bringing us closer together. From a constructivist perspective, it is the world that is expanding in intersecting multiverse. Alternatives to comprehensive knowledge as a platform for action, and tools to support them, must be instituted and generally acknowledged. Collaboration is one such alternative, allowing collaborators to filter the complexity of a rich and dynamic world. A significant difficulty in developing tools for collaboration is the perspective of the collaborators; each brings different skills and views to the effort, and a different set of social expectations. Collaborative tools must find a way for widely divergent social needs to be met without imposing the sometimes unexamined biases of the tool developer. A constructivist perspective is a first step towards recognizing and dealing with those biases.

THE OBJECTIVIST DILEMMA
It is the context of objectivism that has historically characterized our view of reality for several hundred years, and has provided a largely unexamined set of assumptions underlying planning, theory, and belief. From our objectivist perspective, we strive to adapt all historical social structures to address complexity and new needs, yet much of our immediate well-being (income, social identity, emotional and material security) remains dependent on these same historical structures. This need to adapt entails not only institutions such as schools, government agencies, corporations, and traditions (such as courtship and the work week), but concepts as basic and diverse as success, failure, language, logic, faith, honesty, family, wealth, loyalty, and self interest.

Objectivism requires "objective distance." It presumes that a distance from practice was necessary to produce operationally valid theories of practice. As this theory was hierarchically superior to the individual circumstances of practice, so the theoretician became historically elite in relation to practitioners. Objectivism is now successfully discredited as having universal explanatory power, but the institutions it created still stand, and certain conflicts exist between people and the unreplaced organizational structures that continue to direct their lives.
CONSTRUCTIVISM, SENSIBILITY, AND DESIGN

Constructivism is a philosophical response to the objectivist dilemma. The basis of Constructivism lies in the perception that there is no one unity that serves as our world; instead, we exist in multiple consensual domains. Each of those consensual domains has its own sensibility. In his essay "On Constructing a Reality," Heinz von Foerster illustrates that the environment as we perceive it is our invention, and that cognition is essentially the process of computing descriptions of reality in an infinite recursion of descriptions, in which reality is ultimately not proven, but is implied (von Foerster, 1974). While this works quite neatly for single organisms, when there are multiple organisms, multiple representations of reality must be allowed. Therein lies the consensual domain; we believe in reality not as sole individuals, but as communities. Constructivism, thus, does not recognize "objective distance." Collaborators participate in a consensual domain. When their exchanges are communicated via a medium such as electronic tools, that consensuality must be supported in the structure of the tool. Practice emerges from a community and operates within the social controls of the community. While a tool may be perceived as a social control, it is only a second order control; a first order social control is sensibility.

Sensibility and Collaboration

Artists historically unite theory and practice, and operate out of a sensibility rather than by mechanically applying theory to practice. In the case of effective artistic collaborations in which all collaborators contribute creatively, unspoken features develop beside those that are spoken, and communication is tested and retested through the shared object until collaborators more and more produce changes that both please and surprise the other by illuminating the structure of what is being shared between (or among) them. Through such collaborations the communication of the artwork and its validity beyond the individual are ‘proven’ by the continuity of fit of new decisions with the other participant(s). Such communications are rarely spontaneous — each participant must learn the scope of the sensibility of the other. In artistic practice, sensibility can be described as a partly unconscious, idiosyncratic and self-correcting system of allowable and disallowable responses to an internally and/or externally determined subject. The technologist’s collaborative efforts, in contrast, are usually centered on a disciplined creative process that has rules, guidelines, and traditions that require ‘fit’ and validation of practice to theory. Is sensibility constructed by individuals, or by communities participating in a consensual domain? The artist and the technologist may disagree but the implication to design is clear: we cannot expect any artifact to generate the same response from everyone, whether that artifact is art or tool. The shared experience of a tool is necessary to prove its usefulness. We can approximate shared response by understanding sensibility and the social domain, and apply that understanding to the process of design.

THE PATH OF ART

Intuition and the Artist’s Process

The partly unconscious feature that operates in a creative sensibility may be called “intuition.” Because it is partly unconscious, intuition cannot be tested for reliability. In an objective environment, this disqualifies the artist, as usefulness in application requires proof of repeatability. However, intuition can be seen as concealing a mechanism which, in operation, is tested and corrected by the artist in an ongoing way. The artist extends comprehension to include intuitive responsiveness to a field of indicators, a context that provides through coded uses of colors, sounds, and gestures, a historical basis for self-communication, linking the present sensibility to those past through the art object. Appropriateness is judged through this process, as are such features as expressiveness, or iconic power of form, color, sound, or gesture (Galuszka, 1988). The artwork creates a context of its own past that acts to test each present action. Through this process the artwork suggests to the artist when a change constitutes an improvement.

The artist is often disinclined to analyze this process. “Analysis,” as D.H. Lawrence says, “presumes a corpse.” Analysis seems inappropriate to vital and partly unconscious process. Analysis may demystify inspiration, and thus deaden or betray it. It is unclear that the artist has anything to gain from...
analysis, as the self-testing artwork is the final word in adequacy. Yet, the growing appetite for creativity in other fields indicates that the process of the artist, if understood, may be profitably applied elsewhere.

Creative speculation vs. analytic closure: patterns, not conclusions
It is possible to engage scientists and artists working together for understandings of creative process because the general background is one of creative speculation, rather than analytic closure. In an artistic environment, answers are likely to exceed the original questions, or deviate from them. This can be modeled as "falling short" of adequacy, or as a basis for opening further opportunities for new questions and for new question/answer relationships in an atmosphere of shared understanding. Such understandings are patterns rather than conclusions, as problems are established outside the parameters of evidence.

Marcelo Pakman (Pakman, 1989) says "uniqueness is perhaps the most general characteristic of human experience." This characteristic is continuously embodied and reembodied in art. Consider the traditional art of painting, which Peter Schjeldahl describes as "both the best symbol of, and unbeatable vehicle for, individual consciousness" (Schjeldahl, 1991). Painting offers the possibility of referring to experience by means of improvised systems of interlinked phenomena. As history dependent in construction these improvisations sometimes reference, by means of common codes, an accepted sensibility. And sometimes not. Understandings in art are more often than not misunderstandings, in objectivist terms, because they cannot conform entirely to the "intention" of the artist. From a constructivist point of view understandings are created in relation to the artwork, and validated by internal consistency as tested by the individual viewer — there is, in this view, only understandings in states of development, rather than more or less deviant views. Indicators such as gestures, icons, shapes, sounds, etc. are loaded with protocols which mark possibilities for decision. As indicators reference consensual agreements across diverse sensibilities, they provide opportunities for consolidating parts of understanding within the whole. This is apparent in the design of human computer interfaces. Interface designers make choices based on social coding, where colors have meaning in different domains: physiology (color perception/color blindness), psychology (green=life, red=vitality) or culture (death = black in western world, white in Japan). Both the painter's and the technologist's artifacts exist in a coded relationship, one which may escape the viewer, especially over time, as the cultural nuances cease to persist.

Thus artists can be thought to work out of sensibilities, that is, out of complex and unique personal dispositions. It is from this source that concepts, intuitions, and decisions proceed. This sensibility is open and adjustable to the effects of experience, and as such is continually restructured. The accretions of decisions and descriptions in a painting seek to join into something that expresses to someone a particular, single, unique feeling. When a sensibility-based idea or intuition is consulted for judgment — for instance, on deciding on what about a painting needs improvement — an artist is likely to explain that a particular of the work "doesn't feel right" or "I like it, but it doesn't go with the feeling of the whole painting." It is this unity of feeling that establishes the true boundaries of a work of art. Imagine such a changeable, sensibility produced object, existing between two or more people in conversation.

THE PATH OF TECHNOLOGY
Collaboration is fundamentally the conversation between two or more people to produce a common result. Not necessarily a synchronous activity, nor literally a conversation, collaborations are a type of unity that can be conducted over time and space through the use of communications media. Where collaborations may have been limited in the past to face-to-face engagement or the exchange of materials through human or postal intermediaries, new communications media allow a much wider variety of means and, possibly, ends.

Various processes of collaboration are fundamental to all kinds of teams that communicate face to face and remotely. However, the technology tools designed to specifically support collaboration are not yet in common use. The design for electronically sharing resources has progressed slowly over the last decade from the use of storage and communication tools such as file servers and email to collaborative software and computer mediated environments. However, desktop collaborative computing products are still not a part of the standard repertoire of everyday business software. Given that the increasing complexity of the world provides an incentive for sharing resources and working collaboratively, and given that groupware products are commercially available with a wide variety of features and costs, it bears examining why there have been few commercial successes. Many researchers have done so, and evidence is accumulating that the nature of collaboration requires the design of support systems that include not only technology systems but social systems. Furthermore, the tools must be designed with a respect for sensibility, creativity, and feeling. It is, we believe, the tool designer's lack of emphasis on these aspects of design that prevents technology solutions for collaboration from succeeding.

Intuition and the Engineer's Process
Technologists generally make design decisions for group systems based on their own intuition or on research results garnered from extremely constrained tests. As early as 1988 Jonathan Grudin pointed out that one failure of computer supported cooperative work applications is our lack of experience with evaluating social, motivational, economic, and political factors (Grudin, 1988). Lyytinen et al. pointed out that the model which consists of "a small cohesive team with fixed participants, a clear task and shared goals is not necessarily appropriate in informing the design and examination of [electronic meeting systems]." And consequently, too homoge-
ncous and simple a model of meetings results (Lyytinen et al., 1994). Some group objectives are tangible (develop a report, create a picture) and some are intangible (agree, get to know each other, cooperate). The design of collaborative technology must take into consideration both sorts of objectives and the fact that some group work is not driven by objectives at all. Lyytinen et al. make an elegant point: research about software created to support business meetings must be extended in scope to investigate the role that these meetings play in the larger social fabric. Similar results have been published by other researchers, urging contextualized or user-centered design. Technologists operate within an extraordinarily narrow conception of collaboration based on building consensus and imposing limits to creativity. Grudin illustrates this nicely with a case in point: "a management group considered using an issue based IS in which issues, arguments, counter arguments, and decisions are entered, creating a record of decision making that could be used to communicate, review, and explore alternatives. The plan to use the system was abandoned because the manager wanted the group to project a strong sense of consensus. The explicit record of opposing positions that the application would immortalize was politically unacceptable" (Grudin, 1994). In contrast to the conception of collaboration as consensus building and converging on agreement, the creative essence of collaboration is the ‘friendly interference’ between participants that gives the collaboration forward momentum.

Creative speculation vs. analytic closure: patterns, not conclusions

If technologists cannot trust their own intuition to build successful collaboration tools, how do they proceed? The constructivist viewpoint is helpful; the designer needs to regard the audience for the artifact not as a unity, but as multiple communities, each of which may have different communication needs and preferences. There is not, then, a “recipe for success” in a cookbook of design. There have been several attempts at generalizing development principles for collaborative software, among them Cockburn and Jones’ set of principles, strategies, and techniques. They implore developers to maximize personal acceptance, minimize requirements, and minimize constraints. While these are fairly vague instructions, the authors offer some examples and warnings: beware of rigid models and theories, minimize dependence on structure and format (of preexisting tools or standards), and be aware of when you, as a designer, are making choices that will affect the user (Cockburn and Jones, 1995). Grudin offers eight challenges to collaborative technology developers. One of these is the failure of individual intuition; another is his challenge regarding disruption of social processes. He states that “Groupware can lead to activity that violates social taboos, threatens existing political structures, or otherwise demotivates users crucial to its success” (Grudin, 1994).

Merging paths towards purposive tools

How might the paths of artists and technologists meet when it comes to facilitating collaborations in a general way? Technologists may do well to consider the reflective nature of the art object as a social object, wherein consensual and subjective features intermingle in the mind of whoever considers it. As such an object, the artwork reflects a certain reassuring but encoded mindfulness, a quality of knowledge of its own position. This characteristic of art, in objectivist terms, can be called ambiguity. Ambiguity may be entertaining, provocative, or poetic, but it is not useful. In constructivist terms the artwork can be considered as a coordinating mechanism, a thing that reformulates the collective and individual communications of all audience members whose sensibilities become engaged with it. It does this through a flexible metaphoric structure. Such a structure, when discussed, has the potential for embodying a variety of points of view that, in spoken or written language, with its biased protocols, would appear to be nonsensical, ephemeral, paradoxical or contradictory.

In spite of its evanescence of meaning, the artwork persists as a continuing and concrete point of reference. It is worthwhile to consider the technological possibility of responsive objects that have the characteristics of artworks. Such an object might be constructed to reflect the developing culture as sensibilities meet in collaboration. Changes in the object would come to have meaning to the collaborative group. It would be available as a reflection of a project in any state in its development.

The imaginary tool of the information age, a translation of artistic creative process into a general use instrument, is not very different from the operating cultural artifacts we find in our everyday experience. This collaborative tool is first and foremost a social object, something separable both from the problem and from the participants. It has the capability of defining sensibility/identity and of creating a communal culture.

We posit two recommendations to designers: understand sensibility, and acknowledge that requirements for collaborative technology include reducing constraints and eliminating structure to the greatest extent possible, to allow groups to build their own structure and develop their own sense of protocol and appropriateness for exchange. An excellent technology to deploy for tools meeting these requirements is object technology. Using Apple’s OpenDoc as an example, objects can be containers or can be contained; a container is a perfect sharing device, which allows members in a collaboration to offer any type of content they wish as an object. That object can be manipulated independently of any other object. In our container, we can manipulate virtually limitless types of content in place: maps, virtual worlds, clocks, charts, movies, and sounds, and we can cruise the Internet all from within a container that puts few limits on what can be contained. Everyone could look at our container and see how changes are affecting the project, or the group. This unstruc-
tured capability offers possibilities for developing media through which collaborators can construct their own socially coded sensibility; the sharing space functions as an artwork, a responsive object shaped by its authors.

To make tools viable across consensual domains, they must be flexible and able to embrace multiple sensibilities. To that end, tools for collaboration must not dictate social structure and should be constructed as adaptable, adaptive systems.

AN AGENDA FOR EDUCATION

An intrinsic part of art education is the cultivation of conversations around “nonverbal” subjects. The success of artists in constructing and maintaining discourses around difficult and abstract subjects is under-appreciated or under-acknowledged. This may be of special value in advancing understanding across existing frontiers by opening new areas of consideration.

A similar emphasis on the abstract should be introduced into the disciplines involved in the creation of technology artifacts, by increasing attention to culture, context, flexibility, and the participation of art and the artist’s sensibilities in the process of technology design. The design of tools for collaboration presents a special challenge: designers must relinquish reliance on their individual intuition, and learn to listen and create in a community process. Researchers must develop methods for examining and documenting social coding, not as examples or instances, but to uncover the process of coding, to allow for it in the structure of collaborative technology. Tools for sharing must be fluid enough that the participants in the collaboration define the structure of communication. The process of design must allow users to inform, create, and sustain their own social coherence.

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On the Choosing of Ontologies in the Design of Information Technology

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ABSTRACT
Today, when we design applications for information technology, we must choose a single view of the world (ontology) that the application will adopt. The closer this choice is to the user’s view, the easier it will be for the user to employ that technology in achieving their ends. Improved methods for designing ontologies include watching the users at work, and including the users in the design. However, no matter how well we choose the ontology during the design, the choice will be wrong for two reasons: different users will view the world differently, and the world changes. This paper proposes that we must break out of this dilemma by taking advantage of the ability of information technology to reflect its own design: make the ontology be a central part of the subject matter of the application. Then permit users to interact with the application to adjust the ontology to their needs as the circumstances arise. This makes ontological design central to use, and requires that we understand how to support non-professional designers (users) in the design of ontologies.

Keywords
Ontologies, application design, end-user design

INTRODUCTION
This paper addresses a central issue in designing information technology—the question of what view of the world the technology will adopt. Today’s information technology is amenable to taking almost any view of the world.

However, that view is built into the technology when it is designed. The technology is not able to adjust that view once it has been put into use. But the uses that IT is put to are not completely determinable at design time. Even for systems which are purpose-built, the needs of the users will drift with time. Therefore there is an inevitable gap between the view that the technology has of the world, and the view that the user has of the world, and the user will have to bridge that gap (the ETIT mapping) in order to put the technology to use.

This paper looks at some sources of that gap, and some approaches that have been taken to addressing it. It argues, however, that these solutions have all been achieved under a set of assumptions that while successfully supporting current practice of building systems, leaves those systems falling way short of what we could hope for them.

This paper then proposes that we should demand more of our IT systems. We should require that they let the user play a role in determining the view to be taken of the world, while the system is in use. The paper explores some consequences of this sharp change in directions in the design of IT systems.

ONTOLOGIES AND INFORMATION TECHNOLOGY
Information technology (IT) is about the world. That is, IT is based on computational mechanisms which are regarded as representing real world objects. Unlike much other design, the design of IT is designing technological entities which are “about” real world entities. This relationship of designed IT systems to the world is central to understanding the practices of designing and using IT.

This design goes roughly like this: Pick some area of human activity to be supported, determine what technical objects will support that activity, design these objects, decide how to represent them, implement the design, and put it to use either in experiment or reality.

Since these objects represent the world, a key part of this process is designing what view of the world the technical system will take. That is, how will the world be “registered”. Computer scientists have borrowed from philosophy (and only slightly misused) the notion of “ontology”; the study of what objects there are in the world.

Choosing an ontology is thus a central part of designing information technology (IT) systems.

For example, consider the design of an computer-based address book. Presumably the book contains addresses. What’s an address? There is nothing predeterminded about this; we have to design it. Suppose we say: an address has a person’s name, street name and number, apartment number, city, state, ZIP code and country. What could be simpler? A food deal, because we haven’t half begun to answer the questions which immediately arise: Is a phone number included too? How about e-mail address? What about PO Box numbers? What about suite numbers? What if the address is in Canada which has provinces and territories, and postal codes which are not 5 or 9 digits? What’s a person’s name made up of? Is the address book only for persons—what about families, or companies, or movie theaters? And so on, and so forth. Lots of decisions. And they all have to be made.
And or course they can be made quite differently: An address book (in Jeff Raskin’s “Information Appliance”) is a big long galley of text composed of characters and carriage returns (new lines?). It is regarded as being broken into blocks by inserting two adjacent carriage returns. The user can put anything they want in a block of text. That’s it. Great for storing and finding addresses. Also great for lots of other things too, so maybe its not an address book. But if all I use it for is addresses, then as far as use is concerned, it is an address book.

And there are many designs in between: An address (in the Sharp Wizard) has 8 fields: name, phone, address, and 5 others that the user can name anything they want. Each field is a block of text. And so on.

So there are many different ways of looking at the world. Which seems perfectly obvious.

That there are so many different ways of looking at the world, and that these can all lead to perfectly acceptable IT systems, points at another characteristic of IT: in the hands of good designers and developers, information technology is very malleable. Although there are restrictions on implementation, on the whole IT presents few restrictions to the registration we might choose for an application. IT is a perfectly projective medium: whatever you want it to be you can make it be. And while this is a wonderful boon to applications designers (little ontological restriction imposed by medium), it equally offers little help in the central task of choosing how the application (meaning, of course, the designers, the developers, the users) will look at the world.

And the decision matters. The rest of the design will depend mightily on which registration of the world the designers choose. Beyond that, the work that the user must do will also be determined by that choice. The design will have consequences for the users, setting expectations, making some things easier and others harder to achieve. As a result, as designers are painfully aware, the design is not about technology; the design is about a practice that the technology will enable. This practice is somewhat determined by the design of the technology, but it is completed by the users (often with the help of other intermediate designers: VARS, indigenous experts, colleagues and friends) as they put it to use in their activities. Often these activities are not at all what the designer had in mind. In the end, all involved will have cooperated in creating a socio-technical system which will help (one hopes) in getting an activity done.

At the center of this practice is the ontology – the registration of the world – that is built into the design. It is often augmented by intermediate design, possibly put to completely different ends by the user, but centrally there nonetheless.

SOLUTION 1. IGNORE THE PROBLEM
The time-honored tradition for choosing an ontology is to simply ignore the problem. That registration is a matter of significant concern seems often to come as a surprise to designers of IT software. By trade or predilection, the decision of how to view the world is one that is either invisible or one that is regarded as “not my job”. Programmers expect the design to specify that for them. Software designers, while recognizing that the choice is theirs, often expect that the registration is a matter of simply thinking it through either alone or with the client (the person for whom the application is being created) in the process of establishing the project. Even those who recognize that the users might have to be involved seem to often think that sitting with the users for while and asking some questions (“talking to users”) will readily expose what is perfectly obvious and non-problematic if only given a little thought.

As a result, the consequences of the choice are often invisible as well. In a situation in which users have little say about the ontology, and the resulting system is introduced as a done deal, users become skilled in mapping what they can of their work into the system, and working around the system for the rest.

For example, when office procedures are automated, it is common for the developers to adopt the normative (manager’s) registration of the world which holds that people follow office procedures in much the same way that computer code is executed by a machine — in a non-problematic, easily-defined and understood carrying out of the required steps. Of course, anyone who has actually carried out an office procedure knows that things aren’t always non-problematic, and that the activity is in reality often somewhat divergent from the nominal flow. When the office procedures were implemented using paper forms, this divergence could be handled by tacit agreement among all involved. For example, if the boss has agreed that something should be bought, but the paperwork is not prepared before he goes on vacation, people will place the order and get the signature later when he returns. But when a computer is used, it is not at all prepared to handle divergences. If the procedure says the boss signs before the order goes out, then that is the order things will happen, and whether it is good for business or not, the order will wait if the boss is away. So when such a computer system is put in place, people learn how to either order without the computer, or how to fool the computer into thinking the boss has signed, even though the boss hasn’t signed at all, yet.

So the traditional approach is to ignore the problem of choosing a registration, and hope that the consequences, such as people working around the system, will not be too severe.

SOLUTION 2. RESOLVE THE QUESTION.
An alternative approach is to take seriously the fact that getting the best registration possible will be better for the work. The activity is regarded as not being easily understood, and effort is put into understanding the work and how to view it so as to best support it. Various kinds of practice have devel-
opied for this, depending on what time scale and degree of understanding is desired. The most thorough-going and time-consuming of these arise out of anthropology, applying ethnographic techniques including video analysis to “make the familiar strange.” ”User studies,” including surveys, focus groups, site visits, talking with users, yield less certain or probing results for more practical expenditure of resources. “Participatory design” techniques, including future workshops and situated prototyping, explore both the activity and the role of technology by engaging users in the design of new systems 2

These techniques, often grouped under the name of “user centered design” are highly regarded in the field of human-computer interaction for focusing the design around the real needs of the user. The intent is to resolve the question of what ontology is best for the intended design by making the choice a matter of serious study.

DIFFICULTY: MULTIPLE VIEWS

Most systems are used by more than one user, and often they are used by more than one class of user. In fact, systems are most useful just when they tie together the work of many people in different parts of an organization or indeed across organizations.

With a diversity of people, come a diversity of needs from the system. And the existence of a diversity of needs calls into serious question the assumption that there is a single best registration that will keep everybody happy.

For example 4 , when NorTel, a Norwegian Telephone Company, was creating a new system for managing its physical facilities, two sharply different views were held as being the best way to look at the equipment. The line repair folk who worked in the field were naturally oriented to the physical reality of the equipment, and therefore wanted lines ordered by which cable they were in, or which transmission tower they used. In contrast, those who managed the connections from the control room were oriented to the logical reality of a connection (vs. a line), and wanted things grouped by capabilities (digital or analog, capacity, reliability, latency) and were less concerned with how that connection was implemented. No single view was adequate; these are simply incompatible views.

Again, the traditional approach is to ignore the problem. The most common way this is done is to simply choose the view of one group and ignore the views of all the rest. This often happens when one group has more power than the others by virtue of either position (e.g., management’s view is taken as authoritative) or control (e.g., the management information folk are implementing the system, so they can make it be whatever they want). This works even when choosing between existing applications, often through giving the requirements of the more powerful group more weight than the requirements of others groups.

Again, the alternative is to attempt to expose a resolve the matter. Indeed, some of the techniques of participatory design are aimed at revealing just such conflicting differences of view. And many of the design techniques for creating new systems are designed to resolve them. That is, because a system must in the end adopt some registration, the goal must be to create a compromise that keeps most people most happy. Sometimes this is achieved by having a single compound view adopted with all the translations between the registrations panned for. In the NorTel case, for example, both views of the physical plant were supported and as it turned out having both views was helpful to both groups, not least of all because they could do a better job of “talking the other guy’s language” where that was required.

However, even when a composed view can be achieved, the needs unmet by the compromise will again be a mismatch between the system view and the user view; and people will “go around the system” to meet those needs.

DIFFICULTY: CHANGING VIEWS

Much though it would appear that system designers would like to deny the fact, time marches on, and needs change. Worse yet, registrations change. Which can mean that the central point of a portion of the design, and the running system based on it, can be called into question.

For example 3 , the form used by the order clerk who took orders for copier supplies from Xerox customers had a field for address. As time went on, this was replaced by two fields, one for shipping address, and one for billing address. The registration of the world changed: billing is done to a different place than shipping. The system was changed to reflect the changed view. In a related example, a clerk was asking a customer for a shipping address, and was answered with a question, “When will the supplies be delivered? You see, the copier is on an ocean-going barge and I’d like Xerox to ship them to the next port-of-call.” Because the clerk did not know when the supplies would be shipped, she got a name and telephone number from the customer, and put “Call Bob at 555-1234” in the shipping address field. The intent was that the shipping clerk would recognize that the address was not an address, but rather instructions for getting an address, would call, get the address then, and ship accordingly. The world had changed, Xerox had run into mobile copiers, and the notion of an address changed to include a procedure. At the time, the clerk was working with paper forms, which imposed no constraint on how the field was completed. However, if it were automated, no doubt the computer would be smart enough to enforce a registration of the notion of address which would preclude a procedure.

The solution here is almost always to ignore the problem, primarily because the problem occurs while the system is in use and so there is no chance for any change to be made before it is needed. People almost always work around the system. Sometimes system designers sometimes anticipate
changes and provide generic escape-hatches, such as comments fields.

Alternatively, systems can be redesigned to incorporate the changes. This can take time, as for example with one Canadian mail-order company in which the inability to change the billing software meant that changes in promotional pricing had to be made six months in advance. The more timely the fixes, the more costly. And the cost of keeping systems current often is many times the cost of developing them in the first place.

In the end, as change is inevitable and continuing, we must take the view that the development process is also something that is inevitably continuous, whether in changing the technology to reflect the changing world and/or in changing the working-arounds that people develop to meet those needs.

Finally, change interacts with the difficulties introduced by multiple views. When people develop independent work-arounds, there is always the possibility that these independent designs will conflict with each other. Indeed, if the views driving the needs are conflicting, then conflict is not only possible but likely.

**A DIFFERENT VIEW OF THE PROBLEM.**

In all of the above, it has been assumed that the system has at any moment in time a single view of the world. And the challenge is to find a single registration that will meet all the changing needs.

However, it is interesting to note that the system as a whole does not subject itself to this constraint. People have differing views, and they change.

So the suggestion is that maybe we are being too demanding on systems: that they have but a single view and stick with it until the designers come along and make a new release. Or maybe we are being not nearly demanding enough, in that we do not see the system as having any part to play in that essential system activity of changing to adjust to the world. We have been blinded by the computer scientists and the managers who think that the way to solve all problems is to get everyone together, decide the answer, and then act. Plan, implement, and live with it. The business schools are changing that story now, looking beyond planning to the just-in-time everything and seeing strategy as response to change. It is time for the computer scientists to move on from the 60's to the 90's and take a serious look at change.

But how do people manage to work in systems which encompass diversity, both between people and over time? First, they admit that this is the case, that the system as a whole is not necessarily "singing off the same page," nor that what is happening today need be the same as what happen tomorrow. Second, they are prepared to detect when differences in these viewpoints matter. They are constantly alert for strange behaviors and are ready to entertain the idea that they are encountering a difference of opinion. And third, they are prepared to deal with the differences when it matters.

However, there are a lot of skills associated with these capabilities. And most of them are far beyond the capacity of today's computers. We simply don't know how to make computers capable of being self-aware at the level that people find so instinctive.

**SOLUTION 3: HONOR DIVERSITY, SUPPORT CONFLICT.**

The answer lies not in having the systems behave like people, but rather having the systems help people behave like people. Instead of exiling the discussion of change to beyond the system, make the system a carrier of this essential human and system activity.

Entertain: First, we have to enable systems to contain more than one view of the world. Instead of being ontologically single minded, make them ontologically pluralistic, capable of dealing with a changing world in multiple ways. This requires that the system be explicit about its own ontology, at least able to present it for view when people want to know. This requires a language for discussing ontologies, registrations, framings.

Detect: Second, systems need to be able to help people detect that things are strange, and shift into a reflective mode, to step back and think about the ontological framing of the problem. At least, this means that systems need to have a very different sort of response to difficulties than they have today. Now, when strange things provoke either interactions with dialog boxes the handle the "errors" when that kind of strange-ness has been anticipated, or crashes when it has not. And furthermore, it must provide for the different views to be seen and compared.

Deal: And third, systems must enter into the process of helping the user change the way things are. Such modification does not need to be couched as "programming," and in fact it better not be, since programming is not a skill that people are ever likely to have. It may be simply a way of allowing people to get in and help out when things are strange. Consider, for example, what small change could be made that would enable the procedure to be put in the field where an address was expected; or more carefully, what change could be made to the system so that such changes as "make it take a procedure here too" are expressible and implementable by mere expression. When such is possible, we will have opened up the arena of ontologies to the system and its users; we will have moved from closed to open ontologies.

The above is not a solution, for it does not offer an answer as to how we should to these things. What I am offering, to this conference which is looking to the future of design is the warning that in the area of IT we are not doing as well as we
need to, and that design in this area needs to make some major changes.

In particular, we should expect that systems will come to play an increasing role in their own design. And further that the design will not be done by the manufacturers alone, but rather will become the expect province of the users too.

We must therefore support design, not by designers, but by everyday folk. We will have an expectation that everybody will be lay designers. To do this, we will have to understand lay design well enough that we can help the system participate and support it.

Which brings us full circle: The application is now design. And what is the ontology of design? How do we register the world when supporting design? Objects? Annotations? Versions? Rationales? Media? Roles?

I have little idea. But I believe that these are among the central questions that we should be asking ourselves as we think about design of IT systems.

To do it, we will have to get beyond those who think that they own the design and the process of design. We will have to get beyond the computer scientists who are unaware of the problems of choosing registrations or who choose not to take them seriously, or who think that only they can build systems. We will have to get beyond designers who think that only they can design systems. We will have to get beyond domain experts who think that only they know the right thing for their arena.

Not that these experts are not necessary. Quite the contrary. They are required to set up the framing of the design work that they now have to turn over to all us regular users. Just as anybody can define financial computations because framing designers designed cells in spreadsheets, and just as anybody can now define file systems because framing designers developed the notions of files and folders, so we as framing designers (meta-designers) must create the frame within which anybody can design their own systems.

Possibly this will be completely domain-specific. But I doubt it. I think there are many things about designing that apply across domains, things about choices, and reasons, and the way it was yesterday, and translating between views, and ownership, and quality.

CONCLUSION
This paper is an informal review of the practices of selecting registrations (ontologies) in the design of IT systems. It addresses the possible conflict between different views which are often extremely consequential. It discusses the fact that world changes. It discusses the techniques that have been used to address these issues.

It finishes by suggesting that we have a long way to go in this area and asks two questions. First, why is it that the designers get to choose the ontology; why not let the user have a stronger hand? And second, why is that there should be only one ontology in the system; why not let the system take part in supporting the struggle between views of the world? That is, I want to challenge the fundamental assumption made in the design of most IT today: that the ontology is decided at the outset, and is closed to further discussion thereafter: closed ontologies. I propose that future design should rest on a technology of open ontologies, so that the ontology of the system becomes a matter of continuing design, design continued in use, and design – and particularly the framing design of ontology selection, becomes the province of the user.

NOTES/REFERENCES
1. In fact, we could be a bit more careful. While address books are supposed to be about addresses, the ontology that is chosen is often some mix of registration of the world and registration of the technical object we are creating. And the final registration of the world arises in practice. If I put movie theaters in address blocks, that’s my view of the world: theaters are worthy of addresses. Still, the more the system is shared, and the more important it is that everybody agree on what it means, the less room there usually is for individual adjusting of the meaning to personal purposes. The designed ontology becomes the one everyone has to live with.

2. Lucy Suchman studied this distinction in an Accounting Office, and reported the surprising results in Office Procedures as Practical Action: Models of Work and System Design. ACM Transactions on Office Information Systems 1, 4:320-328; 1983.


4. This example is from an in-depth study by from Kari Thoresen and reported in Computers in Content: Joining Forces in Design. Aarhus, Denmark, August 14-18, 1995.

A Trajectory of Artificiality
and New Principles of Design for the Information Age

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ABSTRACT
From a likely trajectory of design problems, the paper identi­
ifies several design principles that can be expected to inform
design in the next century. Underlying them is a shift in em­
phasis from technological to human considerations or from
hardware to information. Along this trajectory design must
increasingly afford a diversity of meanings (as opposed to
realizing fixed functions), respond to many stakeholders (as
opposed to catering to serviceable end users), address
interactivity and virtuality (as opposed to materiality), sup­
port heterarchies, dialogues, or conversations (as opposed to
standardizing social practices), rely on a second-order sci­
ence for design (as opposed to a first-order theorizing, by
engineers or ergonomists for example), generate knowledge
that opens possibilities for design (as opposed to re-search­
ing a past for previously existing constraints), develop gradu­
ate design education programs that continually rearticulate
design discourses (as opposed to reproducing design tradi­
tions).

Keywords
Artificiality, human centeredness, design principles, infor­
mation, interactivity, stake holders, discourse.

INTRODUCTION
Not even thirty years ago, design meant industrial design:
creating functional mass-products that would contribute aes­
thetically to material culture. Designers of that time elabo­
rated its prototypes: fabrics, furniture, home and industrial
appliances, as well as (industrialized) architecture and (re­
producible) art. Dominating that time was the 19th century
design principle:

Form Follows Function.

This concern for production and functionality still exists in
various niches but has been surpassed by very different con­
cerns in a world that is infinitely more complex, more imma­
terial, and more social in focus, a world in which diverse dis
courses reign side by side, and a world afforded by mediating
technologies of unprecedented carrying capacities. This world
of computation, of information, of electronic networks has
seen a tremendous intellectual growth in which Herbert
Simon played an important role. I will relate the following to

changes since Simon’s pioneering work on The Sciences of
the Artificial (1969). Several of his theses have not borne the
fruits they deserve. Others have been overcome by unfore­
seen developments that now pose exciting challenges.
New principles of design, a new science for design, and a new
kind of activism seems to be emerging. I want to correlate
these with a trajectory of artificiality that design should be
realizing as it moves on.

A TRAJECTORY OF ARTIFICIALITY
For me, this trajectory begins with the design of products and
passes through five major classes of design problems. Each
rearticulates the preceding, thus generating a history in
progress:

DISCOURSES
  generativity
  rearticulability
  solidarity
PROJECTS
  social viability
  directionality
  commitment
MULTI-USER SYSTEMS
  informaticity
  connectivity
  accessibility
INTERFACES
  interactivity
  understandability
  configurability/adaptability
GOODS, SERVICES, & IDENTITIES
  marketability
  symbolic qualities
  provincial aesthetics
PRODUCTS
  utility
  functionality
  universal aesthetics

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Products, largely industrial, are designed in view of their utility, functionality, and an aesthetics that, for reasons of applying to large markets, claims universality. In pursuit of these, the responsibility of designers coincides with that of industry which terminates with the end-products of industrial production. Products are conceived for an ideally rational end-user and in disrespect of cultural diversities.

Goods, Services, and (brand, corporate, ...) Identities are market and sales driven. Utility and functionality is secondary to recognition, attraction, and consumption. Goods, services and identities are products only in a metaphorical sense for they reside largely in the attitudes, preferences, memories, loyalties, etc. of large populations of people. In developing them, designers are additionally concerned with marketability, with symbolic qualities that are widely shared within targeted consumer groups, and their work ultimately drives the generalization of commercial/industrial/corporate culture with its diverse or provincial aesthetics.

Interfaces. Computers, simulators, and control devices are products in the above sense (and where designers concern themselves with their appearances, they also treat them as such). But more important is to see these non-trivial machines as extensions of the human mind, as amplifying human intelligence. Miniaturization, digitalization, and electronics have made the structure of these intelligent machines nearly incomprehensible to ordinary users, and thus shifted designers attention from internal architecture to the interactive languages through which they could be understood and used. Human-machine interactivity, understandability (user-friendliness and self-instruction), (re)configurability (programmability by users), and adaptability (to users' habits) became new criteria for design. The crown of such one-user-at-a-time interfaces is (the idea of) virtual reality.

Multi-user systems (nets) facilitate the coordination of human practices across space and time, whether these are information systems (e.g. scientific libraries, electronic banks, air plane ticketing), communication networks (e.g. the telephone, internet, WWW, MUDs), or the archaic one-way mass media. Designers of multi-user systems are concerned with their informaticity, connectivity, and the social/mutual accessibility they can provide to users.

Projects can arise around particular technologies, drive them forward, but above all are embodied in human communicative practices. Efforts to put humans on the moon, to develop a program of graduate education in design for the information age, etc. involve the co-ordination of many people. Projects are always narrated and have a "point" that attracts collaborators and motivates them to move it forward. Projects can never be designed single-mindedly. Designers may launch projects, become concerned with their social viability, with their directionality, and how committed its contributors are in pursuit of them, but no single person can control their fate.

Discourses live in communities of people who collaborate in the production of their community and everything that matters to it. By always already being members of communities, designers can not escape being discursively involved with each other and participate in the growth (or demise) of their communities. The design of discourses focuses on their generativity (their capacity to bring forth novel practices), their rearticulability (their facility to provide understanding), and on the solidarity they create within a community. This workshop is a perfect example of creating an albeit short lived community that accomplishes things discursively.

DESIGN PRINCIPLES

Along this trajectory of design problems, each progressively creates new challenges that need to be met by new social or technical inventions. Each also brings new criteria into the design discourse and calls for new design principles that enable designers to move on. Let me elaborate nine of them as guidelines for future elaboration and immediate research funding decisions:

1. Meaning is the only reality that matters
One of the fundamental insights of product semantics for design is that people never respond to what things are but to what they mean to them. This has lead to the irrefutable axiom of design:

\[
\text{Artifacts never survive within a culture without being meaningful to their users.}
\]

I am suggesting that no contemporary design decisions can violate this axiom. Designers who do invariably fail - or design just for themselves and only accidentally for others with compatible understanding. I should say that Simon had no appreciation of the significance of meanings. What mattered to him was an accurately conceived ontogeny, an engineering rationality that everyone had to (or should be trained to) comprehend and enact. Nobody could anticipate the social consequence of computational technology and the complexity of the information we are now facing. His positivism lead to what we now recognize as an authoritarian epistemology which is no longer suitable in information-rich environments. In fact, as soon as we move beyond the engineering of functional products, we need to be concerned with what they can possibly mean to users and with the multiple rationalities that people can bring to bear on them. Consequently: Form does not follow function but meaning and design has to make sense to others.

Acknowledging meanings as a primary target of design considerations is saying that the diversity of individual (user) conceptions matter as much as if not more than the (techno)logic of the designers and engineers.

2. Design must delegate itself
When developing simple functional products, designers can still be experts in specifying how they have to look and are to
function, much as engineers do. This mono-logical expertise eroded when industrial products came to be considered as marketable goods or services whose values depend on the preferences of potential buyers. The design of goods, services, and various kinds of identities, granted users a voice, however minimal, in what entered the market. But the marketing of combinatorial systems of products enabled users to become local designers in their own right, at home for example. Designing reconfigurable (programmable) computers made it even clearer. In the information age, designers can no longer claim a monopoly on design. Design must be delegated and dispersed with the artifacts it creates. Arranging furniture, composing home pages for the WWW, and programming computers are design activities indeed. The point of design lies in enabling others to do it as well, albeit within the confines of their own resources. Desk top publishing made graphic designers the first victims of this principle. This technology enabled ordinary secretaries to do what graphic artists had done before. Unlike MD’s who manage to guard their profession by licensing, design can not protect itself that way. Design is a fundamentally human activity. Professional designers can only be ahead of others along a trajectory of artificiality they pursue. In other worlds, design is not a privilege but a gift to other fellow human beings. It is the willingness to boldly walk where others have not dared to tread.

3. Artifacts (are) created in networks of stakeholders
The idea of an “end-user” is a myth that originated in our pre-industrial past. Industry appropriated it as a way of limiting its responsibility for its products. Designers who see themselves as user-advocates often react against the single-minded interests of the providers of goods, services, and identities. None of these address what happens after products are brought into circulation. Even the most traditional artifacts not only live different lives - as ideas, prototypes, merchandise, tools, symbols, museum objects, recyclable matter, or public problems - they also typically become a concern of very different kinds of people - investors, engineers, owners, users, bystanders, interests groups, consumer advocates, ecologists, etc., each claiming a different stake in them. Virtually every technology attracts stake holders in its support as well as in its opposition.

At least since the widespread use of computers, stake holders have become far more aware of each other than in previous periods. They organize themselves through various media and are able to coordinate their interests and resistances to what designers propose. While the designers of interfaces therefore can not ignore the stake holders and user cultures that emerge around any idea or technology, the designers of projects are of necessity parts of them. It is only in such networks that designers’ ideas can come to fruition.

In additions to the “politics” enacted in networks of stake holders, the design of information age artifacts also tend to draw on vastly different knowledge domains, requiring a kind of interdisciplinary cooperation that was previously unheard of. This suggests the need of a large scale democratization of design decisions and the distribution of responsibilities to all those willing to contribute their conceptual or material resources to the process. In architecture the beginning of this attitude has led to what is called participatory design. The emerging collaborative technologies - from conference systems to concurrent engineering to rapid and distributed modeling - now offer radically new ways of bringing different stake holders into communication with each other, especially including users, even interested bystanders, critical opponents, or eager beneficiaries. Add to this the vast amount of text electronically available, the result of this networking is a totally different environment for designers to practice.

4. Interactivity replaces materiality
Technology resides less in its materiality than in its social uses, in how users make things happen, create artifacts and handle them in the presence of each other. After all, a word ending with -logy denotes knowledge, logic. Simon shifted our attention from the ontology of the natural to the logic of artificial, but failed to see that his very “project” dissolved material products into our dynamic relationships with them. Meanings too are made. They are not a property of surfaces (as presumed by styling) nor inscribed in static symbolisms (as marketers and designers of goods and services like to treat them). Nor are they derivable from ergonomics or the kind of cognitive science that goes for formal logical accounts of operations and stimuli. They are invented and brought to bear by people needing to cope with particular artifacts or achieve something with them.

As the hardware of computers exceeds user comprehension, interfaces came to mediate between human cognition and computational processes. We experience the design of human interfaces as the key to the human use of complex artifacts and, in retrospect, this has always been true, even for simple tools. Product semantics concerns itself with such meaningful interactions, with how users make sense of and act on what they face, using compelling metaphors as aid to understanding, and building user instructions into software. Beyond interfaces, the interactivity that makes projects succeed is largely coordinated by compelling narratives, by involving dialogues, which carry the notion of an interface to a higher level, albeit mediating among even more complex human collaborators. Making information systems usable is like making narratives compelling, and means designing - not products - but the affordances of human interactions. Interfaces are interactive gestals without materiality.

A minor but not unimportant addition: At the dawn of the information age, the small channel capacities then available favored mono-modal artifacts. For example, the telephone reduced multi-channel human communication to voice. But the kind of channel capacities now available allows designers to go back and provide for multi-modal interactive experiences. Virtual reality is trying to recapture these lost territories, albeit clumsily, coordinating interactivity for several
sensory modalities at once, thus approximating the kind of human involvement heretofore known only by being in touch with "real phenomena."

5. Technology thrives in heterarchy, not hierarchy
Simon wrote at the beginning of the computer age. One of the phenomena he explored was the architecture of artificial systems that would succeed in various design environments. To make his point, he considered two watch makers whose assembly collapses into its parts each time they are interrupted in their effort by a telephone order for more watches. Naturally, the one who designs holistically, with all parts organically interconnected, can not compete with the one who assembles sub-assemblies, components of components, etc. until the whole is complete. The latter strategy was also used in the design of ENIAC, the first computer, built at the University of Pennsylvania, which faced a related problem: component failure. Thus, Simon came to celebrate hierarchy and the kind of mono-logical rationality that is typically pursued in the design of highly functional products. This mono/technology creates the need for integrating diversity into common frameworks, for imposing standards and conventions by a central authority, a government, a leading industry, or a designer.

At least since interfaces became a design concern, the value of hierarchy, of formal (mono-logical) languages and of universal standards has come to be questioned. Simon could not anticipate our current trajectory of artificiality. He could not experience that hierarchical systems of some complexity hardly survive in democratic, market oriented and user-driven cultures. By their very nature, information networks must afford considerable conceptual diversity, enable groups to realize themselves in them, and allow individuals to use information in their own terms. The success of the good old telephone network and now the internet lies precisely in the fact of no restrictions on what can be said. The success of information nets depends on their accessibility to multitudes of users, their substantial openness to different uses, and their lack of proprietary standards. In information rich environments, the projects designers begin to tackle - share wares, educational programs, or corporate design policies - are no longer centrally controllable, governable by a single objective, that is, hierarchically organized. Design needs to operate with heterarchical conceptions, embrace a great diversity of meanings, and negotiate its possible outcomes with others. Projects need to provide spaces for a multiplicity of rather different if not conflicting stake holders to enter, feel comfortable, and leave their contributions behind. Although traditional designers might decry the loss of control that hierarchies provided, chaos, heterarchy, diversity, and dialogue are the new virtues of the information age.

6. As intervention, design is not informed by re-search
Design intervenes in the present and creates new futures. Scientific research, by contrast, favors history and thrives on constraints. The hyphen in "re-search" is intended to remind us of its etymology: a re-examination of records already there, an extrapolation of past constraints into a future, searching again and again. re-search assumes that the logic of the past will govern the future as well. However, along any trajectory of artificiality, nothing ever truly repeats itself which is one reason why scientific predictions of technological developments have been notoriously flawed. For designers, what is changeable is far more important than what persists. Science fiction, popular myths, and designers' imaginations turn out to be far better predictors of coming technologies than historical facts. Designers would seriously sabotage their own mission by relying too heavily on re-search as a way of justifying the paths they are proposing to take. Re-search results can not recognize newness. They systematically and methodically fossilize history. Generating knowledge that could support design decisions means reversing the familiar process of re-search. Instead of examining the past for generalizations and continuing trends, designers have to search the present for possible ways to move into desirable futures. "Scouting," "way-searching," "trail-blazing," or less metaphorical, "pro-search" may be a better way of naming the kind of empirical inquiries designers need to undertake. This calls for methods of inquiry that are radically different from traditional re-search.

But design is only partly about assembling parts into new and progressively more sophisticated artifacts, which largely is what Simon had in mind. It also amounts to interventions into networks of ongoing user practices that change the social fabric of many people's lives. Some technologies merely replace old practices by new ones. Others expand or limit the horizon of human experience. All affect how peoples live together. I am suggesting that the commitment to the re-search of a positivist science - which generates observer- and user-independent knowledge of past events - prevents us from coming to grips with the consequences of informed actions in the minds of stake holders as well as on the technological developments they help to bring about. We need a very different kind of paradigm of inquiry, perhaps along the line of Donald Schon's Reflexive Practitioner, certainly one that acknowledges the dynamics any design activity sets in motion.

7. A science for design must be a second-order science
Designing artifacts with as well as for use by others implies knowledge of these others' understanding. In an information age, designers must either have this understanding or systematically acquire it. However, this understanding is not the kind of understanding we need to assemble functional products, the kind of knowledge that Simon extensively elaborated, or what is needed to design information systems, which Simon began to make available. It is designers' understanding of users' understanding, an understanding of understanding, or second-order understanding for short. Second-order understanding assumes that others' understanding is potentially different from ones own. By contrast, first-order understanding, the kind of understanding that engineers need and the natural sciences have provided us for thousands of
years, completely ignores the conceptualizations that (other) humans bring to it. First-order understanding is mono-logic, second-order understanding is multi-logic (dialogic or interactive). Second-order understanding radically breaks with the widely shared illusion that scientists could take a God's eye view of the world and that all humans, conveniently excluding scientist, are biased, have distorted perceptions, limited capacities, and therefore can not see the true nature of things. Second-order understanding also is dynamic in that it accounts for the possibility that artifacts change their meanings in use, that new artifacts always intervene in their users' understanding, and that we too change our understanding in the process of designing artifacts with and for others. Interfaces can hardly be developed with first-order knowledge (unless the designer can impose his or her conceptions on every user). In human communication, messages are sent in the anticipation of their receiver's understanding. Thus, information always bridges two kinds of understanding and creates a dynamic interweaving of these understandings. Projects can not possibly grow in first-order understanding. A second-order science generates a wholly new kind of knowledge which is central to design in an information age.

8. Graduate design education must redesign design
To see graduate education as an institutionalized way of preparing designers for better paying jobs would not be worth the effort. To offer graduates an understanding of existing trends, for example what the information society is all about, or to familiarize them with the latest technology would not be enough. Walking on a trajectory of artificiality that is paved by its artifacts means pursuing a vision that is ahead of its time and rearticulating at each step what design is or could be. I suggest that graduate education should create designers that are capable of critically examining and re-designing the intellectual infrastructure of their design community. This calls for developing design methodologies, enhancing the conceptual tools for design practices, and creating new opportunities for design as a profession. Design education would be a natural place for designers with a Ph.D., but far more important is their creative contribution to design scholarship. Although Simon never envisioned design as moving along a trajectory of artificiality through and into rather different worlds, his writing prepared designers to embrace at least the world of computers. He could be considered a model of the trajectory of artificiality through and into rather different worlds, his writing prepared designers to embrace at least the world of computers. He could be considered a model of the trajectory of artificiality.

9. Design takes place in languaging
Simon taught us, correctly I would add, that the cognition of living organisms actually is quite simple. What makes their behavior appear to be so complex, is the complexity they face in their environment. I must note that such a statement occurs in language and implicates us, humans, in ways Simon hardly realized. Not only have contemporary artifacts increasingly become language-like - they are recombiable into numerous forms, change their meanings in the contexts of their use, can be rearticulated by different users, and be reproduced in different environments - the very environmental complexity that Simon talked of and we face indeed is the complexity of our languaging (which is not merely using a vocabulary instrumentally, but living in communication with others). Product semantics is one approach to design that capitalizes on the recognition that distinctions within and among artifacts are drawn in language, that the qualities we attribute to artifacts start with those available in language, and that designers cooperate with each other and with clients in a language they can handle. Language enables designers to receive specifications, to make presentations to clients, to argue the virtues of particular design solutions, and to empirically inquire into the social roles that artifacts acquire within a culture. 99% of all design occurs in talk and it is amazing that we seem to know as little of our languaging as fish are said to know of water. This is not to down play the role played by other modes of interaction. Visual perception, tactile experiences, emotions, and kinesthetic senses of our bodily being with artifacts undoubtedly are central to design. But even in this workshop, 99% of what happens is talking, gesturing, projecting slides, and a written version of the contributions, this paper included, will be on the World Wide Web, printed in book form, and we all are convinced this will set the switches for the shape of design in an information age.

I am suggesting that the road toward an information society is paved by our own languaging, by our developing adequate discourses by which we generate the opportunities we desire and conceptualize all the artifacts we need to realize to move on. Design discourse is what keeps the community of designers together. Design discourse generates artifacts whose meanings matter. Design discourse provides the ground on which institutions can thrive (even those we might not wish not to nourish). Design discourse enables the education of designers, the teaching of design principles, the formulation of design methods, the public celebration of exemplars, as well as the construction of guiding futures. Designing a discourse probably is the most human way of designing worlds, including ourselves, for it embraces all its speakers in proportion to their willingness to contribute to the process. A design discourse contains all the principles of design.

I take these loosely worded design principles not merely as responding to the information technologies we know, but as initiating a process by which we can critically examine and conceptualize design and the history of artifacts to come.

RECOMMENDATIONS
When funding design efforts or scholarly work towards new information technologies, NSF should give preference to proposals whose investigators:

1. ... respond to the multiplicity of meanings different stakeholders or users may bring to a technology and resist the temptation of universalizing their own techno-logic.
2. ... *delegate* to users *as many design decisions as possible*, develop frameworks or languages that encourage unanticipated uses, and avoid designs that leave others no interpretative spaces.

3. ... commit themselves to *work as partners with stake holders* who quite naturally organize themselves around any proposal or idea and/or to create multi-disciplinary teams for realizing a proposal within networks of such stake holders - as opposed to providing ideal users with designer’s solutions to designer’s problems.

4. ... *focus on human interactivity*, on the design of interfaces, and on treating artifacts primarily as reproducible gestalts in ongoing, multi-modal, and language-like interactive practices and only secondarily as industrial and marketable products. The reality of information “products” resides in human interaction or communication.

5. ... *favor heterarchy* over hierarchy in information designs, favor open non-proprietary software architectures over the creation of inflexible standards (in the service of a dominant stake holder), and allow artifacts to develop lives of their own in contrast to attempts to prescribe or control their use.

6. ... *engage in “pro-search”* (the systematic creation of presently possible paths towards desirable futures) rather than traditional re-search (the systematic extrapolation of past constraints and their projection into a future).

7. ... *contribute to a second-order science of the artificial*, to an understanding of others’ (stake holders’) understanding of artifacts, to conceptions of reality that embed others’ reality constructions in that of the investigators - in opposition to a first-order science that limits itself to orthodox and monological world constructions outside the (first-order) scientist and treats information as unrelated to human concerns.

8. ... *encourage educational technologies* and programs that *drive a trajectory of artificiality into the future* by making scholarly contributions to design discourse, conducting second-order inquiries into possible design practices, developing new interdisciplinary design methods, and testing the viability of critical appraisal techniques, claims, and arguments. In an information age, the new generation of design graduates have to be capable of continuously rearticulating (redesigning) design as a visionary profession, as a knowledge based institution, and as a generative social practice. Traditional (art)historical approaches to design research and education shed light only on a past.

9. ... are aware of their own *languaging* and constructively intervene into the *interactions between language use, perception of reality, and the coordination of design practices*, examine how different forms of languaging create (or close) alternative trajectories of artificiality, and critically evaluate the viability of alternative professional design discourses.
Cooperative Problem-Solving in the National Aviation System

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ABSTRACT

The operation of the aviation system in the U.S. depends upon the collaboration of a distributed collection of agents at airline operations control centers, the FAA’s Air Traffic Control Systems Command Center (ATCSCC), regional Traffic Management Units (TMUs) and in the cockpits of aircraft that are enroute (just to name a few of the agents involved). With current technologies, some of these agents are computers, while others are human. Furthermore, each agent has its own set of goals and priorities, and has access to a unique set of tools and information.

This paper focuses on two types of cooperative problem-solving: Cooperation between a person and an “intelligent” computer system, and cooperation among several people that is mediated by a computer system. Central to the successes and failures of such systems are the nature of the communication patterns and information exchanges, the distribution of roles and responsibilities, and the incorporation of feedback and process control loops into the system. The theme of this paper is the importance of taking a broad systems perspective in designing complex technology-supported enterprises and in recognizing the importance of the influence of human factors concerns on individual, group and system performance.

Keywords

Cooperative problem-solving, human error, aviation.

INTRODUCTION

In aviation, medicine and education, there is increased emphasis on the design of computer-supported cooperative work environments because of the increased capabilities of a number of enabling technologies. In such applications, computers play two important roles: The computer as an active problem-solving agent, and the computer as a mediator between people. In both cases, a critical concern is the design of the information that is provided by the computer. This concern deals with both the content and form of the information displays. Equally important is a concern over the respective roles of the computer and the people involved in completing various tasks, and the interactions of these roles with the design of the information displays in determining overall system performance.

HUMAN-COMPUTER-HUMAN INTERACTION: THE DESIGNER AS A TEAM MEMBER

One interesting perspective on such computer-supported cooperative work environments is to explicitly think of the computer system designer as one of the team members. As such, the designer has an interesting role. In particular, the designer (or design team) is limited to participation prior to actual task performance, and is limited to communication with the other team members through the design of the system itself. By designing the functionality and information displays for the system, the designer is telling system users what she considers important for a particular task. These implicit messages from the designer can have a tremendous impact on the performances of the system users, influencing the assumptions they make, the data they view and the communications they have with each other, as well as directly altering their problem-solving processes.

The implication of this viewpoint is that system designers need to develop a broader view of information design than is often the case. Not only do they have to ask what information needs to be displayed in order to support particular tasks, they also have to ask:

1. How will alternative displays of this information influence the users’ cognitive processes and performances?
2. How should their limitations as designers influence decisions about what information should be displayed, how it should be displayed, and what roles should be assigned to the various human and computer agents?

An example illustrating such concerns in the context of human-computer cooperation is discussed in Layton, Smith and McCoy (1994) in the context of an intelligent decision support tool designed to assist airline dispatchers and pilots in flight planning activities. On one screen, this system provides a graphical map display for planning a flight or flight amendment. On this map, current and forecast weather in-

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formation can be displayed, along with alternative routes or flight paths under consideration. The user can zoom in on critical regions to view data or graphically sketch alternative routes, and can request the computer to automatically generate alternative routes (subject to user specified constraints defining a “good” solution). On a second screen, the user can view detailed quantitative data about particular flights as well as a view of the vertical profile for a particular flight plan, displayed as a spreadsheet with embedded graphics that show the vertical profile relative to weather concerns such as turbulence.

Although the subjective evaluations of 57 dispatchers and pilots who used this system were very positive (“I love it. I like the idea of being able to see exactly where the route is on the screen right in front of me and see where the weather is in relationship to where the aircraft is flying”), empirical studies have demonstrated that such a system can have an extremely adverse influence on the user under certain conditions. The conditions are those cautioned about above: Situations where the designer has failed to adequately anticipate and communicate the limitations of her design.

Specifically, when this flight planning system exhibits brittle performance, displaying a flight plan that is unsatisfactory because the computer (i.e. the designer) failed to adequately model the situation, users are strongly biased to accept the computer’s recommendation even though they are viewing the relevant data. In one such scenario, over one-third of the users (all experienced practitioners) were biased by the designer to accept a potentially dangerous flight plan. This biasing effect was not due to simple overreliance on the computer. Instead, this effect was caused by a combination of three phenomena:

1. Users started to think of the computer displays as the world, instead of as data about the world (a “videogame effect”);
2. Users exhibited a “justification bias” where, upon seeing the computer’s recommended solution, they developed incorrect situation assessments that were consistent with (i.e., that justified) the computer’s solution;
3. Users demonstrated a number of classic cognitive biases (hypothesis fixation, biased assimilation, confirmation bias, etc.) that interfered with their ability to find a satisfactory flight plan (Fraser, Smith and Smith, 1992).

Studies in this aviation context, as well as analogous studies in medical contexts, clearly demonstrate that such biases are due to the combination of the computer’s role in suggesting solutions to the problem-solving task and the design of the information displays that the computer uses to communicate its solutions and its model of the world. In short, the use of what appear to be highly informative visual displays, when combined with a brittle intelligent agent, can have a serious adverse impact on the cognitive processes of the users.

To reiterate the implications of such findings, they suggest that the designer needs to think of herself as communicating with the user of the system she is developing, and that she explicitly think about how to effectively “interact” with the user under conditions that she has not anticipated.

HUMAN-COMPUTER-HUMAN INTERACTION: REAL-TIME COOPERATIVE PROBLEM-SOLVING

The interaction of the designer with the user is somewhat unique relationship, as the designer must in some sense deal with all possible interactions ahead of time. Important human factors issues also arise, however, in computer-mediated interactions between people who are working together in real time. The national aviation system provides numerous interesting illustrations of this.

One interesting example involves the evolution of the current process for allowing airlines to request non-preferred routes for their flights. Until recently, neither airline dispatchers nor traffic managers at TMUs had visual displays providing real-time displays of air traffic across the country. The net result was that access to information was very compartmentalized, and airline dispatchers had no effective method for requesting alternative routes for their flights. Such displays are now available to both of these groups. The designs of these displays themselves are fairly straightforward, based on design principles that have been established for quite some time. What is interesting, however, is how providing access to such information significantly changed the behaviors of these groups. In particular, access to such data helped the airlines to begin making informed requests for alternative routes, and to press for explanations from the involved traffic managers when a request was denied. Such requests, in turn, led to a new role for central flow control (ATCSCC), that of helping the airlines to get the routes that they prefer. As one airline dispatcher stated: “When we started this, even Central Flow didn’t know where all the choke points were. ... Originally, we’d call and they’d say no. But then it became: ‘Well, if you would just do this, if you’d just make this minor adjustment in your flight plan, we could probably do this. It became a much more collaborative effort.’ The result of this change has been tremendous improvements in fuel efficiency.

(One airline reported making 15,279 requests for alternative routes in a single year, and saving over 13 million pounds of fuel as a result of approved changes.)

The implication of this example is that one of the most important impacts of a new information display is often on the behavior of the affected organization(s). Thus, decisions about what information to provide to whom are often critical design decisions.
CONCLUSION
The theme of this paper is that two of the major frontiers for information design deal with cooperative problem-solving, and that two promising areas for research are:
1. Modeling how alternative information display designs interact with underlying decision support tools to influence the problem-solving processes and strategies of individual users;
2. Studying how design decisions about how to allocate access to information can change group dynamics and organizational behavior.
In short, applications of technology in contexts such as aviation are pushing designers to go beyond traditional considerations based on an understanding of perceptual psychology, and to consider the potential impact of their information designs on the cognitive processes of individual users and on group dynamics within their organizations.

REFERENCES

Collaborative student projects conducted at OSU's Department of Industrial Design are meant to provide opportunities for research and experimentation even on the undergraduate level. Using Product Semantics, the study of meaning in design as a conceptual framework, a class of Juniors recently developed innovative hardware designs for workstations of the information age. This paper describes the students' approach as well as selected results of the project, which was sponsored by the Wilsonart Corporation and supported by Steelcase, Texas Instruments and other contributors.

The ever increasing complexity of modern information products and systems requires new considerations and fresh approaches in their planning and design, or the fair access to this technology as well as its usefulness and broad acceptance will be severely jeopardized. In redefining the role of the users and making their abilities, needs and desires decisive factors in product development, designers today have more opportunities than ever before to determine the shape of artifacts and environments to come.

One such category of consideration, Product Semantics, focuses on the elusive subject of 'meaning' in industrial design by paying special attention to issues such as self-evidence and intuitive interpretation. While the systematic study of Product Semantics as a distinct scientific domain is still in its initial stages, considerable empirical research and work in the university as well as by industry is steadily generating valuable insight into the way users of artifacts 'understand', that is, relate to, feel about, and make sense of products and systems they are involved in, or confronted with.

The goal and intent of the workshop on 'Design in the Information Age' not only triggered, but also strongly affected a collaborative student project at The Ohio State University, where studies in Semantics, and design projects that allow both experimentation with and the practical application of research findings have become a tradition. The situation at Ohio State is further enhanced by the fact that the Department of Industrial Design also offers specialized studies in interior space and visual communication design, and has a strong research oriented graduate program for interdisciplinary ventures of all kinds.

However, the project described here was handled by a group of Juniors in a mandatory Product Design studio course. For them, 'Design in the Information Age' appropriately meant emphasis on hardware - and as a matter of choice on: 'Modular Support Systems and Environments for Information Products'. The Department's track record in contract research and collaborative projects supported by industry helped to attract Wilsonart Corp., the world's largest manufacturer of high-impact laminates for the furniture and construction industry. The company agreed to supply the funding as well as crucial technical know-how for the identification and pursuit of 'visionary design concepts for workstations of the information age'. Target date: the year 2006 - ten years from now.

The particular approach followed by the students clearly reflects the semantic theory's strong bias towards user needs and desires in the context of social, economic, and cultural conventions, standards and trends. Ten distinct phases provided a basic structure for the course, as well as organizational guidelines for the six project teams, consisting of three students each.

1 Analysis of current practices in information processing, and extrapolation of trends into the targeted future.

2 Identification and selection of an area or field of specific application consistent with a genuine need.

3 Focused research with emphasis on requirements, expectations and desires of end-users and other stakeholders.

4 Exploration of relevant and supportive metaphors, analogies, icons, symbols, and other potential manifestations.

5 Generation of initial design configurations based on key performance specifications and desired semantic signifiers.

6 First round of field testing and evaluation of figurational concepts by typical users of the product or system.

7 Concept development with emphasis on technical feasibility, ergonomics and other 'non-semantic' aspects of the design.

8 Second round of field testing and assessment of the emerging design concept by end-users and other stakeholders.
Completion of two- and three-dimensional communication material, and documentation of both approach and results.

While this process at may not appear dramatically different from conventional design methods, it does, if appropriately interpreted and applied, reflect a strong concern for the product's 'meaning' and the way it is seen through the eyes of the user. This paradigm shift is significant for a profession used to arrogantly decide over good and bad design. Exposing students early to use- and user-based 'philosophies' will secure the significance of our discipline in an age of rapid developments and unprecedented challenges.

The ten week academic quarter at Ohio State provided roughly one week per phase in the process, with time contraints particularly severe in regard to step one. It took little effort and imagination, however, to discover that the so-called information age will bring a variety of subtle as well as dramatic changes in the way people communicate and process information at home and in the workplace. Being exposed extensively to information technology from an early age on will enhance the typical user's appreciation of electronic media, and make it much more natural to replace paper for instance as the major information carrier.

The identification of an area of application, step two, was heavily biased towards 'real' needs and special challenges in the activities and workplaces of the information age. Shared office spaces, multi purpose equipment, decentralized or remote access, miniaturization of technology, etc. were just some of the concepts explored that eventually led to the variety of distinct project directions selected and pursued by the six different student teams.

With semantics skewed towards the human users of a system, and an admitted focus of the research on crucial issues only, a set of parameters emerged, addressing such elusive concerns as desires, feelings, emotions, and cognitive models, in other words, trying to understand how users understand. This step three of the approach increased in complexity by the fact that 'users', also called stakeholders of products include those who fabricate, package, ship, sell, install and repair, if not the ones who plan, design, advertise - or even discard for recycling. Often their needs and expectations conflict, requiring ranking and sometimes considering one request at the expense of another.

Main objective of step four was to transform the initially mostly verbally expressed qualities and features into somewhat tangible, dimensional icons - recognizable, if not for all, then at least by those users who matter most. Metaphors, archetypes, analogies and other cognitive models are powerful means of lending desired character to a design, as well as assisting the user in the understanding of how to interact with it. In earlier experimental projects conducted at Ohio State, the search for semantic manifestations, as we call them, was preceded by a listing of semantic attributes, the design should evoke, as well as those it should not. This method will be demonstrated in more detail later when the actual design concepts are presented.

The logical next step five as it were requires the creativity of transcending the metaphors or equivalents towards figurations and embodiment, and thus towards potentially functional, in this case hardware concepts. There is never just onemearing or solution - not to mention various sub-concepts (e.g. adjustment details, lighting fixtures) in need of integration into the principal architecture of a design. Through variations and permutations, plausible concepts emerge that can be modeled for empirical assessment of their function and semantics.

A first round of field testing and evaluation of initial, often rough concepts is a vital step six in a human centered design process. Anything >from informal to formal test methods will work to enable students to see the virtues of soliciting opinions and facts from a target group of 'interactors' with the design concepts. Often, structured interviews in somewhat realistic environments will do, while proper focus group research can render more reliable results at considerably higher expense and logistic effort.

Careful recording of the empirical evidence, and even more so their sensitive interpretation will, and did in this case provide valuable input for step seven, during which the most promising concept matures towards a single and coherent semantic statement with all elements of the design supporting each other. Even with emphasis on semantics, no later than at this point must technical feasibility, ergonomic requirements, and other factual aspects be checked and re-checked, since a structure must not just appear to be stable, but actually be such by virtue of a low center of gravity, or wheels that lock, etc.

At least one more round of field testing should proof the gradual evolution of the overall design concept. Now materials, textures, color schemes, and product graphics should in place to allow the assessment of effects that other semantic media have in the understanding of the design. Once again, careful unbiased recording of users' responses is crucial for the outcome of any test, but so is the act of interpretation. Valuable suggestions by the test subjects are often indirect, hidden, and disguised - something students need to get sensitised about.

Armed with feedback from the most important users responding to full-scale appearance mock-ups (which require far less imagination), refinement began. Dimensions were decided, materials detailed, textures, color schemes, and graphic interface concepts added. But ones again, not just end-users and operators, but time permitting shipping and installation as well as maintenance and repair personnel, possibly janitors.
and housekeepers, assembly workers and recycling engineers should be consulted as well. The list of stakeholders could be long in case of products more complex than the ones dealt with here. Also, concept refinement might realistically happen in cycles with increasing attention to details. Usually, the end of the academic quarter brings this process to an abrupt halt, leaving many issues and aspects of the design somewhat unresolved.

The conclusion of the project was an exercise in documentation of both approach and results. We recognize the need for the preparation of communication material by making it step ten of the process and assure that time and energy is reserved when such commodities become extremely precious. Students are notorious in miscalculating what it takes to wrap-up a project in a self-explanatory manner with models, photographs, videos, computer renderings and animations, sketches, control drawings, and research reports containing such items as trend analysis and evidence of user testing.

Three different interpretations of the assignment to conceptualize ‘Modular Support Structures and Environments for Information Products and Systems’ are to demonstrate what kind of results are achievable with the method just described. They included information age office systems and those for the home, and addressed widely varying use scenarios ranging from the more public to the personal, and from the serious to the playful.

The first concept represents a response to trends in business offices where space is going to be ‘shared’ rather than ‘owned’. Instead of an enclosed room or even assigned footage in a landscaped space, the individual’s territory is reduced to a highly mobile workstation on wheels, minimal in size, vertical in proportion, and hexagonally shaped to allow various configurations for rapidly changing work situations. When pushed in the corner or facing outwards and away, the design provides a certain degree of privacy - while its arrangement in clusters allows groups to be formed as needed to accommodate team interaction and a sense of belonging. The stations are ankered to a floor-mounted ‘boye’, or to overhead outlets that facilitate networking and compound the individual system’s computing power. The principal visual interface is a large screen, although each station still provides some paper storage by shelves (both open and lockable), has integrated task lighting and other features which make the units not only self-sufficient, but affords time sharing amongst office workers. Being also modular, light-weight, adjustable, knock-down, and self-evident, it is easy to see, how not just the actual user of the station, but other parties involved in the station’s total performance were systematically considered in the design.

The evolution of information technology combined with a trend for its diffusion generates a growing demand for alternatives to the centralized business office as we know it. Often labelled ‘home office’, the idea has sparked major research and development and led to a great variety of commercial interpretations. This second concept carries the notion of a compact workstation for the home to an extreme by putting it on wheels and into the basic configuration of a cart. Thus, it visually suggests as well as actually affords ultimate mobility - even up and down stairs, but definitely over interior terrain of all kinds. Such concept is only practical where and when the need for paper in all forms and uses is drastically reduced, and miniaturization continues as a tendency in computer technology. The design is obviously not suited for carting large paper files and heavy books around, except for some reference material which can be stored and accessed through drawers etc. next to and between the wheels. Visual interface is again provided by a large flat screen built into the lid of the unit, with a wide range of adjustment in both height and angle. Ten years from now the cart might become even lighter and smaller than the shown concept suggests, thus affording easy transport from home to home, and possibly limited outdoor uses, not envisioned at this point. The second concept compares to the first like the laptop does to the PC, though with
considerably more versatility and power. It is particularly suited for elderly or physically challenged users, but also for students (of all ages), who want to take full advantage of decentralized learning options.

The third concept centers around the belief that computers need to be demystified, and rather understood as friendly (living) companions in the home - like a helpful hand or a lovable droid. While early design ideas looked more like little electronic 'bugs' spread all over the cyber-house and fulfilling specialized tasks, the concept eventually pursued recognized the need for a more compact and centralized, yet diversly programmable unit of roughly one and one half foot in diameter and two feet in height. It stands upright but swivels like a children's weeble-wobble, and thus can be tilted towards one user or shared with others - even played with and hugged like a pet or toy. With table top elements in between, two or more of the cylindrical units can be connected, stabilized, and transformed into furniture-like configurations which might characterize the homes and households of the information age. Already, computers in homes monitor support systems, provide communication, facilitate learning, leisure and entertainment as well as dozens of other tasks. Linking their functions and physically centralizing them could help in the quest for simplification of interfacing with technology as well.
as its universal accessibility.

There were four more results from the project, addressing four more sets of goals and parameters:

One of the student teams detected a need and market for home computer furniture of more traditional appeal - in this case of a commode or secretaire. Opened up, it provides and defines a compact personal workspace with integrated task lighting, while casters allowed the unit to be moved within the room or home.

Another team pursued the design of a workstation specifically suited for the expected fully electronic libraries of the information age. A large, curved computer screen provides some privacy for viewing and working on an integrated table top. Special feature: an attached chair that slides out of the way to allow access for wheelchair users of the system.

For one group of students the assignment of choice was envisioning the future in home entertainment and conceptualizing hardware based on extrapolating current technology into the information age. Convinced of the social value of leisure activities, the team developed super-screens and components for the projection of virtual realities, and integrated multi-sensory delivery devices for the ultimate illusion.

Public access stations for outdoor settings proved to be a challenge of almost insurmountable proportion for one team of three students. Requirements like systems iconicity, yet self-evidence for users who could be amongst the least prepared for dealing with the intricacies of interface technology (some of them wheelchair or otherwise disabled) constituted only a small part of the problem. Resiliency towards abuse and vandalism, as well as to widely varying weather conditions and a host of additional considerations pointed to concepts based on half-cylinders of roughly 2 feet in diameter that could either be mounted on walls or attached to each other and to a column-like base. This design sounds somewhat unresolved - and it was.

Public access stations to the information super highway will either become one of the tougher assignments for planners and designers, or it might go away, like public telephones could - when eventually everybody carries a cellphone.
Educating for the New Information Profession

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ABSTRACT
More than a decade after the personal computer, the Internet and on-line databases became commonplace in academia, the curricula taught by communication and journalism faculties differs only marginally from what they were in 1980. On the assumption that traditional mass media will undergo striking metamorphosis, this intentionally provocative essay proposes a new paradigm for journalism education. It suggests how universities might help to create a new profession that, like journalism, performs the indispensable function of representing different parties in the exchange of information — but through innovative services that are more conceptual and individualized than is "news."

Keywords
Journalism education; information technology; information society.

INTRODUCTION
Let us begin with a paradox: universities are repositories of scholars whose function is to expand the boundaries of human knowledge. Yet as institutions, universities adjust at a glacial pace to the very changes their faculties document and help bring about. Education in the fields of communication and journalism provides a case in point. Propelled by technology, economics, and public policy, the institutions, processes and impacts of communication and information in advanced societies are undergoing revolutionary change. Universities need to adjust to that reality. Given the pace of change, they need to develop the orientation and practical tools to keep on adjusting more nimbly than they traditionally have.

Communication and journalism faculties house many researchers who are exploring the new information and communication technologies and their implications for society, business, politics, family life. Yet — more than a decade after use of the personal computer, the Internet and on-line databases became commonplace in academia — the curricula that those researchers teach to their students differs only marginally from what they were in 1980. Most courses proceed as if print books, conventional newspapers and magazines, written memoranda, voice telephony, and broadcast television are and will remain the staple modes for storing, disseminating, and exchanging information.

Future journalists in particular are trained to serve an industry that is unlikely to be around in its current form ten years from now. The mass news media have pursued the goal of gathering large audiences to peruse a single information product either simultaneously or in close temporal proximity — for instance, the evening news broadcast or a daily newspaper. It is commonplace to predict that new technologies will shortly make this function obsolete, as consumers gain the power to tailor news reports to their own interests and schedules. That prediction may not come to pass and mass news media may survive, but at a minimum they will compete with customized formats. And the mode of interaction that many persons have with the communication and information media will change; the boundaries between reading news reports and business reports, for example, are already shifting for those who have networked computers linked to the Internet or commercial on-line services. No longer are learning about "news" and reading a trend report about their own business necessarily separate parts of an executive's day.

This paper considers the dimensions and implications of change in communication and information technology for the profession of "journalist" and — on the assumption that traditional mass media will undergo striking metamorphosis — proposes a new conceptualization for journalism education. It suggests how we might think about designing a new profession that, like journalism, performs the function of representing different parties in the exchange of information. Most importantly, journalism represents ordinary users of information to powerholders and vice versa. This same function will be needed as new information technology becomes more pervasive throughout the society and its organizations. The need for reporters who receive bylines and cover beats in conventional ways for traditional news outlets may shrink dramatically. There is already a vast disproportion between the number of journalism majors who graduate from college each year and the number of openings for paying jobs. But the need for professionals who can discover, sort, and communicate information that is relevant, timely, and comprehensible will expand just as quickly. There is a need too for these professionals to design systems or agents that will help untutored users figure out how to get information and how to update their information search routines by themselves. The new professionals can help make productive links between information users and the computer scientists, engineers, programmers and designers who are creating the new information systems, connections that are so often frustrating, nettlesome — or absent — today.

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Those who deliver these new information services will work inside businesses and government as well as outside, perhaps in traditional mass media organizations, perhaps in new forms of information businesses. The skills they need will differ substantially from those of traditional journalists, although clear, incisive writing will remain essential. For example, most journalists gather most of their information via personal observation and oral interviews. The new information professionals will gather much of their information from computerized documents and databases. They may spend more time interviewing people about where to find information than asking them to serve as information sources themselves, and more time interviewing their “audiences” (clients) about their information needs than talking to any direct human sources of data.

**WHAT THE NEW INFORMATION PROFESSIONALS WILL DO**

The central tasks of the profession will be 1) contributing to and harnessing the extraordinary profusion of information becoming available electronically so that it will enhance productivity in service and manufacturing industries, and in all other social, governmental, industrial and commercial processes; and 2) preventing or ameliorating “information overload.” Among the specific required new skills are:

1. Determining how different individuals and organizations use information in the daily flow of their activities, and customizing information packages — their timing, formats and design, not just content — to meet specific individual requirements.
2. Developing and constantly updating algorithms for searching on-line databases and other information repositories.
3. Becoming substantive experts in their own right yet maintaining the generalist’s ability to make connections across disciplines and intellectual paradigms.
4. Collaborating with engineers and other technical experts to develop software and hardware that efficiently serve consumers’ information needs.

Notice that these tasks are almost the opposite of those performed by traditional journalism. Traditional journalists compose for mass audiences, not specialized and individual ones. At least in the ideal, if not in practice, journalists believe that tailoring their productions to the specific needs of customers is little short of pandering. They cover the news, what people ought to know not merely what they want to. Far from constantly evaluating and altering search procedures, journalists follow algorithms and newsgathering routines that have not appreciably changed in decades. Most reporters sniff, and are taught to abjure, developing substantive expertise themselves. As a matter of philosophy they stay away from those who engineer the formats through which they present information — that’s the business side, the “church” from which the “state” of reporters and editors must remain inviolably apart as professional lore puts it.

Thus we are talking about a wholesale reorientation of the profession, one that will buck up against a strong, even canonical professional ethic. In most journalists’ minds, there is a vital and emotional bond linking the norms and practices of the news business with the First Amendment. Their professional self-concepts, even in these times of deep cynicism, intermingle with their sense of America’s core democratic values. Tinkering with these norms and practices risks incomprehension, derision, and instant rejection, both among practicing journalists and within journalism schools. Nonetheless, in the near future, competitive pressures and consumer demands will either compel changes in journalism and journalism education — or else an entirely separate educational enterprise and profession could arise, marginalizing old-fashioned journalists and journalism schools.

Let us briefly consider each of the four tasks of the new information profession listed above. Conceptualizing the information needs of small or individual audiences means literally asking not “what news do these clients need?”, but what information they need. Traditionally, news is defined according to sets of assumptions and largely unthinking practices: news is what happened yesterday and will happen today, news is what the president did, news is “man bites dog not dog bites man” (i.e. news is novel not commonplace). In truth, these strictures are problematic — most news is in fact highly predictable and routinized, and could be little else given the complexity of manufacturing a new product from the enormously varied raw material of any day’s events. Nonetheless these rules define and guide a professional practice that makes “news” in one newspaper or on one TV station look very much like it does in any other. And much of that news turns out to be of marginal relevance and use to much of the audience. Surveys show high public discontent with the media (as with most other American institutions). And studies document that the state of Americans’ knowledge about social and political affairs is no higher now than fifty years ago, before the spread of television and the newer information media.

The new information profession will start not with a stylized, formulaic definition of what news is and assume that is what audiences must receive. They will ask clients, much smaller audiences, what information they need to make their jobs (and lives) easier and more productive. They will provide information about current affairs along with many other kinds of reports, often in the same package at the same time. A human resources Vice President might obtain analyses of the personnel primary results alongside reports on the personnel practices of Fortune 500 companies as discussed in academic journals, combined with continually updated data on employee turnover in her own firm.

With respect to the second function, information professionals will help design intelligent agents for their clients so that they can conduct their own efficient information searches in a variety of databases and other sources. They will also design computer programs or other mechanisms that help cli-
ents modify and evolve their own information search engines. They will not only supply packages of information, but information about how clients can obtain and package, then repackage, information for themselves.

The third skill, becoming substantive experts, recognizes that the information explosion threatens to overwhelm human capabilities. It seems likely that the new profession will develop subfields of expertise, that will perhaps function analogously to the news beat system. Some people will focus on economic information, others on particular industries, still others on specific geographic areas. Yet all of these specialists will need a general expertise in understanding how people use information, how they think and talk about those needs, how to help clients understand their own information needs.

The fourth skill is collaborating with hardware and software designers. This new profession can provide the long-missing active agent that serves the clients of information machines and services. They could eliminate much of the waste that occurs in most organizations where computer and information technology remains untapped or barely utilized because the learning curve is too steep for so many people, and because the designs of the equipment and software are so often so far from intuitive. The new information professionals can provide constant feedback to designers and programmers about what works, what does not work, what new functions are needed. They can become the voice of the inexpert user, the typical person who is not technically inclined but strongly needs the service that the technology promises to deliver.

Exactly what organizational forms and structures will develop to provide such services is another important question, but one beyond the scope of this brief essay. It is easy to envision a variety of configurations, perhaps some new forms generated by the potential of computer networks themselves. For example, a freelance market might grow up in which consumers post "information wanted" notices on the Internet and ask for proposals from anyone who can design an information system fulfilling their demands. In response to such postings, groups of information professionals might form and re-form on an ad hoc basis, linking in cyberspace to perform specific assignments requiring different combinations of expertise, then dissolving and moving on to new projects with a new combination of personnel.

**MAKING THE OLD MEDIA NEW AGAIN**

To the extent that there is a market for mass media in the traditional sense of serving large audiences with common content — and there is a strong argument that there should be, for their socially integrative contributions to building civic life — they will need reinvention. They will confront considerable competition from the specialized delivery modalities. Traditional news media will seem increasingly cumbersome, unresponsive, and inefficient. Viewers and readers will ask why they should wade through 10 or 15 minutes of news on TV, or turn a dozen pages of a newspaper, to arrive at information they want, when they can customize a collection of information reports and use hypertext links to jump instantly among them and related material. Building a new form of mass medium that will include hypertext and multimedia capabilities is in my view merely a specific variant of the larger task facing the new information professional. The same four skills mentioned earlier will be required. In this case the client is more collective and diffuse, but the goal is still to design an information vehicle whose content, mode of operation, flexibility and other traits will help users make efficient (and even pleasurable) use of information.

**EDUCATION FOR THE INFORMATION PROFESSIONS**

The tasks facing the new information profession suggest a strong need for universities to reform their curricula — and their curriculum-development processes — to meet the challenge of changing communication and information technologies. As noted at the outset, universities have developed neither management mechanisms nor organizational culture promoting such adjustment. Based on my personal observation, journalism and mass communication schools appear no more adept at inculcating this culture of change than any other unit of the university. While determining how to refashion the organizational environments of universities must be a central task for those who seek fundamental curricular re-orientation, determining how to do so is beyond the scope of this paper. The first step is almost certainly to spread awareness of how rapidly the pace of change is accelerating, and how much these new developments affect universities and their key constituencies, students and employers. For the purposes here I consider the somewhat more tractable issue of the direction in which journalism and mass communication faculties might move. Here are three examples of the moves needed to educate the new information professionals:

1. Reorient curricula to focus on cognitive, organizational, and social psychology; literature; philosophy; visual and computer design principles; communication theory; and library science. Based on my own experience at a leading journalism school (Northwestern), most of these areas subjects that would cause current and past journalism students to roll their eyes. The vast majority of these students want to develop the basic writing, reporting and editing skills they associate with Woodward and Bernstein and other heroes of popular culture. Many barely sit still for courses in the sociology of mass communications. They — and their professors — must be convinced that the near-term goal should be to expand production of professionals beyond the realm of those who can competently produce "news." The task is to educate persons who can understand how their clients think and what their clients need, who can convey useful information to those clients, while helping them develop their own information processing skills. But there are few professional incentives for journalism and communication educators to turn energetically toward transform-
ing themselves. They face much hostility within the traditional communications professions (who are the alumni and employers with whom they share culture and experience) and among their university colleagues. One urgent task is to develop concrete, practical incentives to enable a few brave faculty entrepreneurs and visionaries to make the first steps: budgetary allocations, leaves of absence, explicit relief from teaching and publishing duties.

2. De-emphasize the teaching of news formulae and standard “who, what, when, where, why” writing frameworks in favor of inculcating skills and habits of conceptual analysis. The first task the new professionals face is getting inside the thinking process of clients, to understand the jobs the clients perform and the information content and configurations they need to do their jobs better. This is not to deny that many persons will still be doing something like traditional journalism, walking the White House beat, going to press conferences, covering speeches. But more people will be needed who can provide these more conceptual information services to clients.

3. Train information professionals in self-reflexivity. While it is fashionable to assert that the media are obsessed with analyzing themselves, with auto-critique, the self analysis is almost invariably superficial, mostly focused on the amount of attention rather than its quality. Thus columnists will bemoan the distracting volume of attention to O.J. Simpson, to Whitewater, to candidates’ private lives. What they rarely do is ask fundamental questions about the definitions of news, the power of advertisers and audiences in shaping and limiting news choices, the fundamental barriers to truth discovery embedded in news routines and human nature. Analogs to these deeper questions illustrate just the kinds of issues that the new information professionals should constantly raise to their clients. They should ask: Why do you need this information and not that? If you get this information, will you understand it? What additional information do you need that you cannot get given your current information search assumptions and routines? Are you aware of what you systematically cannot know, and how to factor that into your thinking?

CONCLUSION
This paper offers an introductory overview to a large and complicated issue facing one specific outpost of higher education and one important profession. It challenges the profession and its educators to rethink seriously the way they define the profession of journalism and educate for it. Such challenges are often ignored, but in this case, the scope of change in communication and information technology is so obvious and so clearly pertinent to the traditional notions of mass media that there is reason to hope for an exception. If the profession of journalism and those who educate in that field fail to meet this burden, the likelihood is that an entirely new com-ponent of education will arise, with journalism and mass communication schools and departments shrinking in size, stature, and influence.
Animated Pedagogical Agents: Design, Artificial Intelligence, and the Next Generation of Educational Technology *

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ABSTRACT
We are beginning to witness the appearance of a new generation of intelligent learning environments that are populated by animated pedagogical agents. By coupling knowledge-based agency with a strong visual presence, animated pedagogical agents provide students with highly customized problem-solving advice and do so in a manner that simultaneously educates and entertains. A product of marrying the representational and inferential features of artificial intelligence with the sophisticated principles of visual design that govern 3D animation, animated pedagogical agents constitute a qualitatively new generation of intelligent educational technology. Because they can bring about fundamental improvements in K-12, higher education, corporate training and lifelong learning, their societal impact is significant.

Keywords
Animated intelligent agents, design-centered learning, artificial intelligence.

INTRODUCTION
As we approach the end of the twentieth century, the educational system in the United States is experiencing a crisis of enormous proportions. Scores on science aptitude tests are declining. Diminished mathematics skills pose significant problems for an already troubled workforce, and literacy rates remain alarmingly low. In addition to the cultural impact these changes foreshadow, their economic implications are severe: with each passing year, US students are less prepared to compete in the global economy. Despite the reams of negative reports chronicling the decline of education, a new generation of educational technology - particularly intelligent educational technology - offers a cause for much optimism [3].

This new generation of educational technology is that of animated pedagogical agents. By combining the inferential capabilities of artificial intelligence with the sophisticated principles of visual design that govern 3D animation, animated pedagogical agents are beginning to provide students with highly customized problem-solving advice, and doing so in a manner that simultaneously educates and entertains. Because of their significant potential for bringing about fundamental improvements in K-12, higher education, corporate training and lifelong learning, their societal impact cannot be overestimated.

Helping animated pedagogical agents make the difficult transition from the research laboratory to the classroom is a challenging undertaking. Because well-crafted intelligent agents cannot be constructed without the studied cooperation of scientists and designers, it is critical that we train a new hybrid computer scientist / designer who is prepared for the rigors demanded of multi-disciplinary collaborative technology research.

This paper introduces the research and educational agendas of animated pedagogical agents. After overviewing the basic precepts of animated pedagogical agents, we describe an implemented animated agent developed in our laboratory and discuss observational studies of students interacting with it. We then describe the educational agendas required for conducting this intensely multi-disciplinary research. Our discussion is illustrated with the research and educational activities currently underway in the IntelliMedia Initiative, a large-scale multi-disciplinary R&D effort being conducted at the College of Engineering and the School of Design at North Carolina State University.

A NEW TECHNOLOGY: ANIMATED PEDAGOGICAL AGENTS
Since their conception more than a quarter of a century ago, knowledge-based learning environments [5, 8] have offered significant potential for fundamentally changing the educational process. It has long been believed --- and recently rigorously demonstrated [15] --- that presenting knowledgeable feedback to students increases learning effectiveness. Despite this potential, few learning environments have been fielded, and the challenge of developing learning environments that are both pedagogically sound and visually appealing has played no small part in this impasse. Fortunately, recent years have witnessed the appearance of a new generation of animation software that enables teams of animators to rapidly create life-like characters. This development raises an intriguing possibility: creating animated pedagogical agents...

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that couple key feedback functionalities with a strong visual presence.

Introduced immersively into a 3D learning environment, an animated pedagogical agent could observe students’ progress and provide them with visually contextualized problem-solving advice. Because of the immediate and deep affinity that children seem to develop for these interactive life-like characters, the direct pedagogical benefits these agents provide are equaled or exceeded by their motivational benefits. By creating the illusion of life, dynamically animated agents have the potential to significantly increase the time that children seek to spend with educational software, and recent advances in affordable graphics hardware are beginning to make the widespread distribution of real-time animation technology a reality.

Animated pedagogical agents should satisfy three criteria: their behaviors should exhibit pedagogical and rhetorical coherence; they should obey time-tested visual design principles; and they should be believable. First, considerations of pedagogical coherence loom large in the design of animated pedagogical agents. Perhaps most central among these requirements is that an agent’s explanatory behaviors be situated [19]: all of its explanatory behaviors — not merely its advisory actions but also its communication of fundamental conceptual knowledge — should take place in concrete problem-solving contexts. In addition, their explanations should obey principles of rhetorical coherence [14]. All of their utterances must be produced in manner that is appropriate for the dialogue context, and the discourse must attend to the organizational constraints governing multi-sentential text.

Second, because animated pedagogical agents inhabit two-dimensional space — albeit one that, by design, closely emulates three-dimensional space — their behaviors should be governed by the conventions of visual coherence. Because the birth and maturation of the film medium over the past century has precipitated the development of a visual language with its own syntax and semantics [16], the "grammar" of this language should be employed in all aspects of the agent’s behaviors. In addition to traditional film language, an agent’s designers can also exploit the behavior cannon of the animated film [17] by computationalizing classical animation principles [7]. For example, the zoom levels of the shots and the positioning of the agent can visually communicate what is — and is not — important.
Third, agents should be believable. Recent years have wit-
nessed a surge of interest in agent believability [1, 21, 4, 2, 6,
13], which we define as the extent to which users interacting
with an agent come to believe that they are observing a sen-
tient being with its own beliefs, desires, and personality. Be-
lievability is a key feature of animated agents for learning
environments. To be believable, agents should exhibit behav-
iors that indicate their alertness, e.g., through visually
tracking students’ activities while providing anticipatory cues
[20] to signal their upcoming actions. Moreover, because
students will interact with animated pedagogical agents over
extended periods of time, it is critical that agents’ behavior
patterns be sufficiently complex that they cannot be quickly
induced. Experiences with students interacting with an ani-
mated pedagogical agent developed in our laboratory (de-
scribed below) have led us to conclude that increasing be-
lievability will yield significant rewards in students’ motiva-
tion as they interact with learning environments.

AN IMPLEMENTED ANIMATED PEDAGOGICAL
AGENT
To address the multiplicity of issues in creating this new gen-
eration of educational technology, our group conducts research
on a broad range of problems presented by animated peda-
ogical agents. We focus in particular on animated peda-
ogical agents whose purpose is to provide instruction about
the structure and function of a particular device or organism.

In developing agent technologies, we take a strongly empiri-
cal approach: we design a new agent technology, implement
it, embed it in a knowledge-based learning environment,
evaluate the student-agent interactions, and iterate. As we
have created pedagogical agents, we have discovered that
adhering to the following design maxims results in the cre-
ation of agents that facilitate learning:

Agent Persistence: Keep the agent in the frame. An omni-
present agent in the problem-solving environment can reas-
sure learners and increase their interest. Although brief ex-
cursions offscreen to obtain a prop can enliven the action,
maintaining a strong onscreen presence provides visual con-
sistency.

Pedagogical Object Persistence: Maintain “in frame” a ma-
nipulable 3D model of the object (or task) being discussed.
Keeping the primary pedagogical object onscreen reduces the
cognitive load that would be imposed if the object were to
disappear and reappear with frequent scene changes.

Agent Immersion: Graphically immerse the agent in the prob-
lem-solving environment. Whenever possible, its behaviors
should be conducted in close proximity to a manipulable 3D
model of the primary pedagogical object.

Verbal Support: Verbalizations accompanied by little or no
actions should be used for brief reminders and interjections.
Verbal meta-comments such as bridging phrases can also usher
in transitions.

Contextualized Musical Score: Complement the agent’s be-
haviors with a context-sensitive soundtrack whose tempo and
instrumentation are appropriate for the current context.

To sequence animated pedagogical agents in real time, we
have developed the coherence-structured behavior space
framework [18]. Applying this framework to create an agent
entails constructing a behavior space, imposing a coherence
structure on it, and developing a behavior sequencing engine
that dynamically selects and assembles behaviors. The first
step is behavior space construction. A behavior space con-
tains animated segments of the agent performing a variety of
actions, as well as audio clips of the agent’s utterances. It is
designed by a multi-disciplinary team and rendered by a team
of graphic artists and animators. The second step is behavior
space structuring. The behavior space is structured by (1) a
tripartite index of ontological, intentional, and rhetorical in-
dices, (2) a pedagogically appropriate prerequisite ordering,
and (3) behavior links annotated with distances computed with
a visual continuity metric. The final step, dynamic behavior
sequencing, occurs at runtime. In response to the changing
problem-solving context, the behavior sequencing engine cre-
ates global behaviors by exploiting the coherence structure
of the behavior space: it selects the agent’s actions by navi-
gating coherent paths through the behavior space and assemb-
lings them dynamically.

The coherence-structured behavior space framework creates
seamless global behaviors in which the agent provides visu-
ally contextualized problem-solving advice. In addition, by
attending to temporal resources, the agent selects and com-
poses explanatory behaviors so as to achieve the greatest cov-
erage of the domain within the allotted time. The framework
has been used to implement “Herman the Bug,” an animated
pedagogical agent for Design-A-Plant [12, 10], a design-
centered knowledge-based learning environment developed
in our laboratory to provide instruction about botanical
anatomy and physiology to middle school students. Given a
set of environmental conditions, children use Design-A-Plant
to graphically design customized plants that can thrive in the
specified environments. In response to changing problem-
solving contexts in Design-A-Plant, a sequencing engine or-
chestrates the agent’s actions by selecting and assembling
behaviors from a behavior space of 30 animations and 160
audio clips that were created by a team of 12 graphic artists
and animators on SGI’s and Macintoshes. To increase the life-
like qualities of the agent, it employs a believability-enhanc-
ing behavior space [11] which are also sequenced in real time.
Finally, it includes a large library of runtime-mixable
soundtrack elements to dynamically compose a score that
complements the agent’s activities.

The agent is a talkative, quirky, somewhat churlish insect with
a propensity to fly about the screen and dive into the plant’s
structures as it provides students with problem-solving ad-
vise. Throughout the learning session he remains onscreen,
standing on the plant assembly device when he is inactive.
and diving into the plant as he delivers advice visually. In the process of explaining concepts, he performs a broad range of activities including walking, flying, shrinking, expanding, swimming, fishing, bungee jumping, teleporting, and acrobatics. All of his behaviors are sequenced in real time on a Power Macintosh 9500/132 RAM.

To illustrate the behavior of the sequencing engine that composes the agent’s actions, consider the following situation in a Design-A-Plant learning session. A student has seen Herman present an overview of basic anatomy, watched him explain external anatomy in a prior problem-solving episode, and very quickly (relative to her peers using the system) reached the third level of problem complexity. As she assembles a plant that will thrive in the current environment, she selects a type of leaf that violates the environmental constraints. This action causes the problem-solving system to invoke the behavior sequencing engine, which has access to representations of: the student’s partial (and incorrect) solution; the constraints and environmental settings in the current problem; a history of previous behaviors the agent has exhibited; and a history of the student’s previous problem-solving episodes.

First, the number of explanatory behaviors to exhibit is computed. Because the student reached the third complexity level quickly, and there are four total levels, the sequencing engine predicts that there will be only two opportunities (including the current one) for presenting explanations. Of the four explanatory behaviors not yet seen, it will show two of them. By using the ontological index structure to find the relevant candidate behaviors and then using the behavior history and the prerequisite structure of the behavior space to perform a topological sort, three explanatory behaviors are selected which are pedagogically viable. Of these three candidate behaviors, two are chosen for which the the sum of the continuity annotations along the best path is minimized. This produces explanatory behaviors of internal anatomy and transpiration.

Next, the sequencing engine exploits the intentional and rhetorical indices to identify advisory behaviors that are germane to the structure of interest (leaves) and the environmental attributes of interest (low rain and high temperature). The media with which to exhibit the behaviors is then selected. The sequencing engine notes that the student has been given no prior principle-based advice about leaves, so a behavior depicting Herman giving principle-based explanations of leaves — and which she will then have the opportunity to operationalize — is selected. (Alternatively, if the student had already seen the principle-based explanations of leaves, an audio-primary reminder would have been selected instead.) The principle-based explanations are introduced by an audio-primary transition in which Herman explains that, “The low rain and high temperature make some leaves unsuitable for this environment. Here’s why...”

Finally, the behavior sequencing engine orders the selected behaviors as follows: the animated segment of Herman explaining internal anatomy; the animated segment of Herman explaining transpiration; the verbal transition; the animated advisory segment about leaves in low-rain environments; and the animated advisory segment about leaves in high-temperature environments. Because of recency effects and the fact that the advisory explanations were communicated last, the student can more easily apply the advice to refine her plant design. She chooses an alternate type of leaf and continues to build the remaining structures.

EVALUATION
To gauge the effectiveness of the coherence-based approach to dynamically sequencing the behaviors of animated pedagogical agents, formative observational studies and an extensive formal study have been conducted with middle school students. First, formative observational studies were conducted with thirteen middle school students using the Design-A-Plant learning environment and its accompanying agent. Each student interacted with the learning environment for forty-five minutes to one hour. As the students designed plants for a variety of environmental conditions, the agent introduced problems, explained concepts in botanical anatomy and physiology, provided problem-solving advice, and interjected congratulatory and off-the-cuff remarks. These studies suggest that animated pedagogical agents whose behaviors are selected and assembled with the sequencing engine can effectively guide students through a complex subject in a manner that exhibits both pedagogical and visual coherence.

The agent was unanimously well received. His pedagogical and visual coherence, together with his immersive property — the fact that it inhabits a 3D environment and interacts with 3D plant models to explain structural and functional concepts — produced strikingly life-like behaviors. His visual behaviors seemed to flow so well that no student commented or displayed surprise during transitions. Because of bookending, many of the agent’s transitions were technically flawless. His verbal reminders enabled students to continue with their problem solving uninterrupted, and during the study students made frequent (and unprompted) positive comments about his physical actions and remarks.

To design the most effective agent-based learning environment software, it is essential to understand how students perceive an animated pedagogical agent with regard to affective dimensions such as helpfulness, utility, credibility, and clarity. Given the results of the formative study, we undertook a formal study of affective dimensions. In collaboration with our Psychology colleagues, we recently completed an extensive evaluation of animated pedagogical agents’ effects on students’ learning experiences. One hundred middle school students interacted with animated pedagogical agents to assess (among other features) their perception of agents’ affective characteristics [9]. The study revealed the persona effect, which is that the presence of a lifelike character in an
interactive learning environment — even one that is not expressive — can have a strong positive effect on student’s perception of their learning experience. The study also demonstrates the beneficial effects of multiple types of explanatory behaviors on both affective perception and learning performance. In short, we are seeing a rapidly growing body of evidence that animated pedagogical agents can have a significant and positive impact on learning.

TOWARDS A MULTI-DISCIPLINARY ENGINEERING/DESIGN CURRICULUM

The promise offered by animated pedagogical agent technologies is considerable. They not only have the potential to significantly increase learning effectiveness and efficiency, but they also have shown themselves to be particularly effective at increasing student motivation. Because of the inherently multi-disciplinary nature of this research, however, developing these technologies on a large-scale requires us to rethink Computer Science and Design curricula. In particular, it has become clear that what is needed is a new hybrid Computer Scientist / Designer: he or she must combine the software design and development strengths of computer science with the aesthetic and visual design skills typically found in the design discipline.

Research and development of animated pedagogical agents draws on a broad range of backgrounds. On the Engineering side, in addition to a variety of skills provided by AI researchers, a successful team must also include expertise in computer graphics. On the Design side, the team must include expertise in multimedia design and production, as well as 3D modeling and animation. These requirements suggest that we should be exploring the development of a new joint curriculum - at both the undergraduate and graduate levels - that fosters an inter-disciplinary approach to the education of the next generation of educational software developers.

Five types of courses should play integral roles in the training of personnel who can develop animated pedagogical agent technology on a broad scale. First, to develop a personalized understanding of the dynamics of multi-disciplinary research and development teams, they must participate in a number of multi-disciplinary courses that involve students from each Computer Science, Design, Psychology, and Education. Second, these students must have a core grounding in computer science, including rigorous training in algorithms, data structures, AI, and computer graphics. Third, students must be exposed early on to digital imaging, graphic design, multimedia production, and 3D modeling and animation. Fourth, students must develop an in-depth understanding of instructional design and the design of educational software. Finally, they must be given a solid grounding in cognitive and educational psychology and experimental design.

As a first step in the creation of this curriculum, the authors have developed and taught a multi-disciplinary course in Knowledge-Based Multimedia Learning Environments at North Carolina State University. Crossing the traditional boundaries between Computer Science and Design, the course attracts graduate and undergraduate students from both the College of Engineering and the School of Design. It is taught by the authors and draws students from the departments of Computer Science and Design & Technology, as well as students from other departments in the College of Engineering, the School of Design, and the College of Education and Psychology. The course covers a broad range of issues in the design of animated pedagogical agents, including: classic architectures for intelligent tutoring systems; knowledge representation for educational software; pedagogical planners; student modeling; microworlds and interactive simulations; coaching and critiquing systems; multimedia production (from storyboarding to the final version); animation and authoring tools; digital image manipulation; 3-D modeling tools; and evaluation methodologies.

The course has been taught for two years with encouraging results. It typically consists of approximately twenty students who work together on either one or two large projects throughout the semester. Perhaps not surprisingly, industry's demand for students with this experience has been exceptionally high. Given its success, we advocate the creation of additional courses such as this one as part of a much larger multi-disciplinary curriculum.

CONCLUSION

Because animated pedagogical agents combine the representation and inference mechanisms of AI with the strong visual impact of 3D animation, they can provide students with highly customized advice and carefully crafted explanations of complex concepts. The encouraging results of students interacting with the first agent to emerge from this work call for a significant national investment in their development. At the university level, we have already begun to see the crystallization of R&D efforts to foster their creation. For example, the IntelliMedia Initiative at North Carolina State University is a multidisciplinary program founded to create state-of-the-art intelligent multimedia educational technologies. Focusing in particular on animated pedagogical agents, this group undertakes a broad range of issues in basic research that examines the computer science, design, cognitive science, and educational problems in designing, developing, and empirically evaluating pedagogical agent technologies.

Animated pedagogical agents have much to offer the educational and training needs of a rapidly changing workforce in a knowledge-based society. Animated agents have the potential to increase learning effectiveness and efficiency on a wide scale, as well as providing significant benefits in increased student motivation. Consequently, our vision is one of permeation: in less than a decade, animated pedagogical agent technology can be developed to a level of maturity that will permit its widespread adoption for all levels of education (K-12, higher education), as well as for lifelong learning in corporate and government arenas. Of equal importance,
it has also become apparent that the intermediate results of this work can themselves be useful artifacts that can play an important role in classroom work in the very near term. Moreover, the rate at which graduating students with knowledge of these technologies are courted by the software industry indicates a willingness on the part of the private sector to commercialize these technologies. In short, the social and economic implications of this work are significant. With proper levels of support, animated pedagogical agents can begin making significant contributions to our children's education and to our workers' productivity in the not-too-distant future.

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Expanding the Design Universe: Thoughts on the Future of Design Education and Practice

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ABSTRACT
Technology has outpaced our ability to fully comprehend and integrate changes brought about in the social and cultural environment. Great technical achievements which have required an enormous investment of time and resources by government and industry are not necessarily easy to use or useful, and as a result they are slow to achieve general application. Design can bridge the gap between technology and the user, based on an updated approach to design practice and education. Mass production and mass consumption no longer provide the best organizing principle for design activities: the focus has shifted from the mass market to the individual. Given this state of affairs and the ever-increasing pace of technological development, what are the implications for design practice and education in the future? Key concepts and issues for investigation include:

1) interdisciplinary approaches to research and education; 2) collaborative teamwork; 3) user-centered design processes; 4) a shift from the design of fixed structures to flexible configurations; and 5) identifying an agenda for future research.

Keywords
Design education, interdisciplinary design, collaborative design, user-centered design, interactive technologies.

INTRODUCTION
“Technologies come first, praxis comes second, theories come third. As a result of this immense shift, the site of critical thought must be redefined” – Taylor, M. and Saarinen, E. Imagologies. Media Philosophy.

Taylor and Saarinen have identified a key problem in predicting the future in the information age – technology has outpaced our ability to fully comprehend and integrate changes brought about in the cultural environment, and we are forced to run faster merely to remain in place. Remaining in place, however, is not a viable option.

I propose that we are already engaged in some activities that portend the future, and should be engaged in others. These activities are based on concepts that will disable the disciplinary and institutional boundaries constraining design education and practice and replace the industrial foundation of modern design pedagogy with human-centered design theory.

Mass production and mass consumption no longer provide an appropriate organizing principle for design activities. The focus has shifted from the mass market to the individual. We communicate on a global scale through electronic/digital technologies and telecommunication systems, and use these technologies for making contact with other individuals, gathering information, seeking diversion, and exploring the growing database of global knowledge and opinion generated by the collective mind. Yet we retain as individuals the ability to filter and select information of particular relevance to us. What was once achieved through oral communication and then through print media is now accomplished by connecting to a vast neural network of individuals linked through interactive communication technologies. Digital information in the form of text, image, and sound is transmitted continuously and instantaneously.

“Digital technologies make information creation and movement into a single substance that is infinitely transformable. Film, vinyl, magnetic tape, paper, photographic paper, ink, graphics, paints – all converted to the digital domain create a new media unlike anything ever invented. This single digital substance can be transformed by the computer (the means of transmission) into any conceivable form...All media become data types” – Davis, B. “Wheel of Culture,” in Contextual Media, 1995.

Given this unprecedented state of affairs and the ever-increasing pace of technological development, what are the implications for design practice and education in the future?

ISSUES FOR THE FUTURE
Key concepts and issues for exploration include: 1) interdisciplinary approaches to research and education; 2) collaborative teamwork; 3) user-centered design processes; 4) a shift from the design of fixed structures to flexible configurations; and 5) identifying an agenda for future research.

Addressing these issues requires a new perspective on design education, one that is more inclusive and less exclusive – one that permits designers to contribute as fully engaged participants and avoid potential marginalization in the information age.
ELIMINATING DISCIPLINARY BOUNDARIES

New technologies and the complexity of design problems related to the development of new applications for these technologies will require the dissolution of boundaries between academic disciplines and the recombination of design content with theory and methodologies from other disciplines. Disciplinary boundaries must be breached because design problems and solutions related to new technologies are prospective in nature and may be multifaceted, requiring an approach from a number of perspectives.

The design curriculum is commonly supported at introductory levels by basic design and process models developed over twenty years ago, and theories and studio projects derived from the Bauhaus foundation course introduced at the beginning of the century. While indisputable value is still to be drawn from these primary sources, conducting design and research in the era of new media and digital technologies at the end of the millennium surely requires a more complex and up-to-date approach to both teaching and learning.

It is important to use current sources of information for solving current problems. Other disciplines are a valuable resource for acquiring this information. Designers engaged in interactive interface design, for example, can search the psychology and cognitive science literature for information on human characteristics and cognitive processes. According to Hix and Hartson (1993) user interface design consists of the behavioral domain and the constructional domain. "Development in the behavioral domain involves human factors guidelines and rules, human cognitive limitations, graphic design, interaction styles, scenarios, usability specifications, rapid prototyping, and evaluation with human users." The constructional domain is populated by software engineers who create programming code, algorithms, and other activities associated with computer science. The extent of knowledge and skills necessary to produce effective and usable interface design requires interdisciplinary preparation and receptiveness to new ideas from sources outside of traditional design practice. If design education does not embrace this approach, it is conceivable that other disciplines with a higher profile and better financial resources (such as engineering) could absorb design as a subset of its activities in interactive system and product design in the future.

Acknowledging the value of information found outside the discipline of design has yet to take place on a broad scale, as evidenced by the fact that designers and design educators are not significantly represented in such organizations as the Special Interest Group on Computer-Human Interaction (SIGCHI) of the Association of Computing Machinery. Members include professionals and educators from psychology, computer science, and cognitive engineering, yet many of the issues and research results discussed in SIGCHI literature are extremely relevant to visual communication, interface design, usability testing, and information design activities. Conversely, visual communication design skills and concepts are noticeably absent in these other disciplines, and they would benefit by an exchange of information in areas such as legibility, semantic aspects of screen design, color theory, and the effective visual organization of information. Interdisciplinary studies and collaborative activities have the potential to benefit all parties.

Interdisciplinary design and research projects that engage problems of new technologies provide valuable experience for design students. One example of this approach is the educational project sponsored by Apple Computer each year for international design programs, with the intention of fostering collaborative interdisciplinary teamwork focused on the application of computer technologies. Another example of this approach to design education at the graduate level is the interdisciplinary collaborative project co-taught by Dr. Elizabeth Sanders, Vice President of Fitch, Inc., and Susan King Roth at The Ohio State University, sponsored by Indiana Bell and Thomson Consumer Electronics (RCA). Video-communication technologies were utilized to teach the course and communicate with sponsors who were located in another state, and the outcome was the development of new products.
and systems for these same technologies. Familiarity with the
technology permits the design teams to address advantages
and disadvantages of use from an informed perspective.

Project teams consisted of graduate students from systems
engineering, business and technology management, industrial
and visual communication design, and communication. (See
illustrations.)

Extended to a global scale, and involving more “experts” and
“users” electronically and interactively in the design process,
this type of project could be seen as particularly well-suited
for the future (see Sanders, E. and Roth, S., 1994).

This view was supported by the Corporate Design Founda-
tion workshop on “Teaching Collaborative Product Develop-
ment” sponsored by the National Endowment for the Arts
and the Alfred P. Sloan Foundation in 1994. It brought to-
gether key members from educational programs engaged in
collaborative teaching and learning that incorporated at least
three different disciplines including design, engineering, and
business, and demonstrated the success and value of the in-
terdisciplinary approach for integrating real-world practice
“backward into professional education” (1994).

FOSTERING INTERACTIVE TEAMWORK
A process intended to foster interdisciplinary teamwork skills
was present in both educational projects. Effective teamwork
is vital to the success of a design and development team, al-
though it is not always easy to achieve given individual dif-
ferences and the fact that both vocabulary and methodology
differ between disciplines. Nevertheless, no single individual
can master all the skills and knowledge areas needed to solve
complex design problems, especially those related to com-
puter technologies. According to Dan Boyarski, Professor of
Graphic Design and Head of Graduate Studies at Carnegie
Mellon University, “No one individual has the experience or
the knowledge to answer all the questions that arise. The so-
lution is in multidisciplinary collaborative work with experts
from various fields participating in the conception and de-
sign of how a person and a computing device might commu-
nicate with each other, in the context of software that sup-
ports work and play” (Boyarski, 1994).

USER-CENTERED DESIGN
As seductive as technology may be, it ultimately remains just
a tool. More basic is the need to focus the design process on
characteristics and needs of the user. If the user is considered
merely a consumer, customer, or passive viewer rather than a
partner, the profusion of products and communication sys-
tems that function poorly will continue to plague the designed
environment. In every design project, students must be
prompted to investigate the needs and characteristics of the
user before placing pen to paper (or hand to computer mouse).
Concept generation should not begin before the design ob-
jective is defined in relation to the user group, or stylistic
concerns will be given undue emphasis over function. In print
or interactive communications, for example, the effective vi-
sual organization of information is of primary concern. Aes-
thetic or formal attributes are also important but should en-
hance and not interfere with function.

User-centered research should extend beyond the use of mar-
keting surveys and focus groups that determine preferences
or establish “price points.” Design research that draws from
ethnographic observation, exploratory techniques, participa-
tory design methods, and investigation of cognitive processes
related to the interaction of the user with the designed artifact
will result in more informed design decisions. The interface
between artifact and user has been a concern of design prac-
tice even before new technologies made this a priority. Ac-
cording to Gui Bonsieppe, the difference between design,
science, and technology (engineering) can be found in ac-
cepted standard practices in each discipline. He states: “The
objective of design activity is neither the production of know-
edge nor the production of know-how, but the articulation of
the interface between artifact and user” (1995).

A SHIFT FROM FIXED STRUCTURES
TO FLEXIBLE CONFIGURATIONS
A shift from fixed structures to more flexible configurations
is apparent in a number of areas including visual interface
design of computer-based systems. For example, the user of
World Wide Web-based graphic programs or systems can
define the structure of information display on an individual
basis, selecting type size, background color, window size, etc.
In other computer programs the potential for adjusting text
size and color is useful for addressing users with special needs,
such as reduced visual acuity or dyslexia.

Navigation through interactive media and networked infor-
mation is determined by the user, and personalized databases
are created and archived for future reference. The linear, se-
quential, impersonal nature of print media is supplanted by
the non-linear, discontinuous, and personal nature of net-
worked hypermedia.

In the networked environment it is significant to note that
users produce as well as consume information. The design of
systems and interfaces must accommodate this fact. The
Internet grows by the addition of graphic images, text, and
sound contributed by individuals. Knowledge of hypertext
mark-up language, or HTML, is no longer required to
build a Website. Individuals define the shifting shape of the
World Wide Web, which is flexibly configured rather than
fixed in structure like print media.

Socially, politically, and culturally there may be an increased
loss of centralized control as information flows freely and
production is the privilege of anyone with access to computer
technology.

Institutional control of education will also be reduced as online
courses and degree programs, even in design, proliferate, and
these programs will reach a much broader range of students than current institutions are able to accommodate. Continuing education for professionals will be in demand as technological change requires upgraded skills. New skills and concepts will come from a variety of disciplines.

MIT's Media Lab and a few other major research facilities are dealing with future technologies in the present. Many of these projects involve design issues, such as the graphic representation of data, new human-computer interaction through gesture, speech, and gaze (Bolt, 1993), and interactive visualization systems for exploring complex information spaces (Lokuge and Ishizaki, 1995). Programs of graduate design education should encourage the exploration of advanced ideas that push the envelope of current design practice and expose students to research and works-in-progress from new projects and methodologies. Bibliographic resources should be compiled so that students, faculty, and practitioners can advance the field by building on accumulated knowledge. The use of electronic networked communications will facilitate this exchange of ideas and information, and raise the level of discourse and investigation, resulting in the development of theory and best practices to support future research and education. A collaborative approach between design and science will enhance the successful integration of technology into everyday life.

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Information Processing and Design Planning

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ABSTRACT
Information most effectively prepared for design is insightful, thorough and optimally organized to inspire ideas. Computers enable the preparation of such information for complex projects; the information network should enable it to be created, manipulated and used where needed.

Structured Planning is a kit of tools for information-age design planning. It helps planning teams to deal with complex, ambiguous projects in both breadth and depth, using qualitative information organized specially for planning and design needs. Its operations demonstrate how design can contribute to the information network (kinds of information and processes for using them), and how the information network can contribute to design (information ubiquity; means for transformation).

Keywords
Structured planning, development, design methods, design planning, design technology, information technology

INTRODUCTION
Thoughtful modern designers have long recognized that design as a combination of attitudes, viewpoints, skills, tools and ways of working holds great value for industry and institutions (Owen, 1992). Until recently, however, it has been difficult to convince successful organizations of that. Today, the stick of economic globalization has done what decades of “carrot” reasoning could not; design thinking is now recognized as a major strategy for the success of organizations (Owen, 1993 article).

The challenges now are to find better means for communicating design concepts, more efficient ways to develop and transfer design technology, and improved ways to describe design information for most effective use in a networked information environment.

Just as design thinking introduces a different approach to the problems of business and institutions, design information is different from other kinds of information commonly used in the information environment, and design planning is different from other kinds of planning. Structured Planning (Owen, 1993, Design for Integrity) is a “toolbox” of methods that makes extensive use of design in formation for the design planning stage of development. This paper introduces the process as an example of both new kinds of information and new kinds of processes necessary in an advanced information system.

DESIGN AND INFORMATION
The appropriate use of design (and design information) requires a model of the design contribution that can be integrated into other understood models. Because design deals with the creation of things (artifacts, communications, systems, institutions), a good vehicle for explaining its role is

![Figure 1. The Quality Pyramid.](image)

quality, a term excruciatingly studied in industrial and institutional thinking today.

The relationship between design and quality is best explained in a pyramid model (Figure 1). The Quality Pyramid has a design core, within which craftsmanship is the first of three levels. From the design perspective, quality in craftsmanship is achieved through attention to issues of engineering design and design for manufacturing.

The second level of the design core is details. Here design contributes to performance, human factors and appearance. Design specialists (engineering design, product design, com-
munication design and others) invent and refine features to make the product work better functionally, work better for people, and work better symbolically within social and cultural niches.

At the third level, concept, design contributes most to success. Concepts that are holistic and thoroughly thought through are qualitatively better (and more highly valued). Typically, products, systems or services designed well as concepts distribute innovations through their features so systemically that they are difficult, if not impossible, to copy. It is particularly in design planning activities at this level that design information plays a critical role.

Capping the Quality Pyramid is product integrity; under it, quality extends outward to corporate, institutional and societal recipients. Products that are conceived, designed and produced with high quality bring praise to the organizations that produce them. Product integrity implies organizational integrity and, extended, speaks well about the society in which the organization operates.

Important to design at all levels of the Quality Pyramid model is a commitment to design information, a kind of information that distills insights and associates them with ideas — a kind of information that is essentially qualitative.

Against the aspirations of the Quality Pyramid, conventional planning frequently fails. In depth, it fails to find and understand the needs of most of the users of its intended product, focusing on the customer and/or "end user", while ignoring the many other users who also have substantial stakes in how well it works — those who specify, transport, store, maintain, repair, adapt and retire the product — to name just a few. Listening solely to buyers (customers) and operators (end users) leads to shallow understanding. In turn, shallow understanding is unlikely to fuel the holistic, thorough thinking necessary for systemically-conceived, conceptually-innovative products.

In breadth, conventional planning routinely fails to conceive the most potent result. Development effort typically lingers little more than momentarily on the issue of what the result should be. Far too frequently, concepts are already decided before development begins. To use an outdoor metaphor, the expert development team is off at the sound of the gun to climb the wrong mountain. If the purpose of climbing the mountain is to get to the highest ground, then it is important to locate the highest mountain before beginning the climb. In today’s world, it is as important to know what to make as it is to know how to make it.

THE NEW DEVELOPMENT ENVIRONMENT
The development process in industry is rapidly changing from a one-step process, in which an already-agreed-upon concept is turned into a specification, to a multi-step process wherein distinct development stages are devoted to initiating projects, determining concepts and developing details (Figure 2). The traditional process for which the issue was only "how to make it" has been reconstituted to three separate stages: how to plan what to make, what to make, and how to make it. The product of the metaplanning first stage is the project, that of the planning stage is the concept. The product of each stage is the "project statement" for the succeeding stage, culminating in the designing stage with a specification.

Metaplanning, the most novel of the stages, is heavily con-cerned with the information environment and the planning and designing processes that use it (Peng, 1993). >From the metaplanning level, development projects are initiated by modeling context, identifying issues, establishing resources, and selecting/modifyng/creating methodology.

Metaplanning is particularly important for full-scale implementation of advanced-planning teams. In the emerging development model, the processes for designing and planning are as much a subject for development as the products they are used to develop. Those responsible for metaplanning are closely associated with those responsible for the development of design processes and the use of the information environment. As better tools for planning and designing are developed or obtained, they are custom-tailored through metaplanning to the goals of projects to be initiated.

USING DESIGN INFORMATION IN THE DEVELOPMENT PROCESS
Within the development spectrum, Structured Planning is a kit of tools for the planning stage, contributing specific remedies for the deficiencies of conventional planning. To solve the breadth problem, for instance, it segments the development process, separating tools for planning from those for designing. To meet the depth problem, it has Action Analy-

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**Figure 2. Three-stem development model.**
Defining Statement

Field Operations are at busy, fatigued end with protective frames. Sound systems can be played by human operators to support manual or remote operations. Considerations must be made to prevent damage to equipment and operators. The task of planning becomes complex when these factors are combined. It is obviously necessary for the maintenance of work stations, to purchase new equipment in place, as time.

Transport is another part of operation that places equipment in potentially damaging situations. In the field, the need for transport and fast return action is present. In the studio, the need for storage in separate rooms. Equipment is moved to the studio from charging areas decent. And in and out of use as equipment is changed or replaced.

The system of the equipment used is for the production and reception of information drains the need of thoughtful strengths to protect fragile systems. Sound recording systems can be easily broken, damaged, or lost. Equipment and systems must be protected from these events. Field work requires special attention to storage and controls. Studio use in free storage, but equipment will be moved, and thought must be given to any projections.

Design Factor

Figure 4. Action Analysis: Functions discovered through top-down analysis.

Figure 5. Design Factor.
sis, a tool expressly designed to seek out users and gain insights about needs from their behavior.

The tools of Structured Planning can be custom-tailored to a project and can be used with other planning tools. In essence, Structured Planning supports concept development in two major ways: (1) it provides a philosophy, framework and qualitative information formats for discovering what needs to be done — with insight for why; and (2) it organizes this information using novel information measures for optimal use by planners and designers.

In its most general formulation, it progresses through five phases.

**Project Definition**

The first phase of Structured Planning defines a project (Figure 3). Working with a project statement and an initial set of issue topics selected as relevant by the project initiators (metaplanning), a planning team investigates the issues, develops arguments and converges upon positions that state the team's intentions. The phase concludes with a set of documents (Defining Statements).

**Action Analysis**

In the second phase (Figure 4), a process called Action Analysis is used to uncover in detail what the product or system being planned must do. The process is a top-down analytic technique for establishing the functions that must be performed by the product/system and its users. The system as understood from the project definition phase is analyzed progressively, first to establish the modes in which it will operate (e.g., for a television production system, studio operations and field operations with their various major submodes); second, to identify the major activities that will take place within each mode of operation (under Production, for example: recording, participating and conducting); and, finally, to specify the functions that the system or user will perform in each activity. These Functions are the "criteria" against which the system must be planned. They usually number in the hundreds, and they reveal what the system must do for many users, not just buyers and operators.

In the process of specifying Functions, particular attention is paid to uncovering problems and opportunities, potential or actual, that arise as the Functions are performed. Insights are gained here for why things work or don't work well. These, along with ideas for how to use this information, are collected in documents called Design Factors. Associated with the Functions for which they were observed, they become a major resource for the synthesis phase of planning and for other development and manufacturing stages downstream in the project. Essential during the project as the bases for ideas, they continue to have value through the life of the product or system (and its follow-on adaptations) as the underlying information on which the design was based. With similar Design Factors from other projects, they define a new form of organizational memory — a record of insights applicable to any project with similar aspects of function. Figure 5 shows a typical Design Factor introducing ergonomic information critical to the kinds of control problems anticipated in the television production system for which it was written.

![Figure 6. Structuring. Bottom-up reorganization of functions based on design considerations.](image-url)
Structuring

Phase three of Structured Planning is concerned with organizing the functional information for synthesis (Figure 6). The Function Structure produced by the top-down analysis of phase two is ideal for uncovering what needs to be done; it is fatally flawed as a model for creative activity!

Because it is created by establishing categories and filling them downward, the Function Structure inherently inhibits cross-category thinking. In the analysis of a housing system, as an example, Functions such as Sense fire and Recognize intrusion would show up in separate categories - probably under Fire Protection and Security. For synthesis, this isolating form of organization is counterproductive. A better organization is one in which Functions are placed together on the basis of whether they have potential for using components of the developing system in common.

In the housing example, an infrared heat sensor able to detect a developing fire might also be able to sense an intruder, suggesting that the two Functions should be considered together when ideas are being developed. Cross-category thinking is stimulated by this form of organization, and the potential for holistic, multifunctional solutions is increased significantly.

In the structuring phase, Structured Planning's computer programs work from the bottom up using this kind of approach to reorganize the Functions into an Information Structure (Figure 6). This hierarchy of Functions (and their associated Design Factors) is especially well suited to the creative needs of a planning team. The reformed clusters bring together Functions from disparate categories, and Functions can appear in multiple locations. The Information Structure more naturally represents conditions in well-designed artifacts and institutions.

Synthesis

Because of the attention given during the Action Analysis phase to collecting ideas as they occur (in the Design Factor documents), there are typically hundreds of ideas available at the Synthesis phase. Because the Structuring phase has organized the Functions in an Information Structure optimized for design, there is a "road map" to follow while considering them.

One of the more useful synthesis tools is a bottom-up/top-down procedure that employs Means/Ends Analysis and Ends/Means Synthesis (Figure 7). Working >from the bottom up, Means/Ends Analysis helps the team to understand the new Information Structure through by labeling its nodes. Working downward, Ends/Means Synthesis enables the team to choose branches and select, refine, modify and invent ideas as "means" to meet the needs inferred from the labels. Requiring thoroughness and pointing the way to cross-functional innovation, are the Functions with their associated Design Factor insights terminating each branch of the structure.

Communication

The result of the Synthesis phase invariably is a large number of detailed and highly interrelated ideas. To extract full value from this wealth of material, the ideas must be organized for optimal communication to those responsible for the next stage of development (designing).

The concept is communicated as a Plan made up of an Overview and many Solution Elements, each describing one or more ideas (Figure 8). The Overview presents the major elements of the concept and their relationships. Each Solution Element has a title and four information sections: (1) a list of essential features — what the Solution Element (whether it is a physical, procedural or organizational idea) is
The revolution in computer processing of the last decade brings the concept of a new level of awareness. A variety of inventors, from military techniques and computer-controlled movement in film making to create mapping in computer graphics, have made possible to create realistic three-dimensional images that simulate human actors and environments constructed from data bases.

Environmental Image Mapping takes maximum advantage of this capability both to reduce the size and complexity of the set, and to increase the flexibility and speed at which sets can be constructed and struck. The elements of FY Command's studio systems are designed to work synergistically with this specialized approach to virtual reality.

Environmental Image Mapping
- Speeds the construction of sets and programs.
- Eliminates the high costs of authentic sets through the use of skeletal "for actors only" structures.
- Extends possibilities for program settings so the entire range of environments imaginable in visual data banks.
- Exploits virtual reality processes to enable the same image data to be used for design and finished productions.

Discussion

Until now, studio productions required individualized studio sets. The entire concept of "authentic" work was built around the idea that control of the environment could be optimized only on location - in a studio set. Movie and television sets of the past (tool costly) have ranged from minimal sets, while more than seating with contoured lighting, to mammoth, exceedingly complex and expensive recreations of entire environments.

The revolution in computer processing of the last decade brings the concept of set as new level of awareness. A variety of inventors, from military techniques and computer-controlled movement in film making to create mapping in computer graphics, have made possible to create realistic three-dimensional images that simulate human actors and environments constructed from data bases.

Environmental Image Mapping takes maximum advantage of this capability both to reduce the size and complexity of the set, and to increase the flexibility and speed at which sets can be constructed and struck. The elements of FY Command's studio systems are designed to work synergistically with this specialized approach to virtual reality.

Figure 8. Communication Content as plan

CONCLUSIONS

Design, fortified with appropriate tools, can contribute much more significantly upstream than downstream in the development of new products, systems, institutions - anything created by human endeavor. The tools required include design tools and information handling tools.

The combination is potent, deserving recognition in the design of both the architecture of the internet and the design tools to use with the internet. Design tools of the kind represented by Structured planning benefit substantially from an architecture designed to facilitate qualitative information handling; information sharing; cooperative creation of information; evolutionary structuring of information bases; and construction, retrieval and presentation of design information. The architecture of the information environment benefits reciprocally from the use of design tools like Structured Planning to develop concepts that anticipate the needs of internet users more fully and creatively.

Based on this perception of interaction, a number of complementary contributions can already be detected.

Design is contributing to the information age:

- models to describe quality that reach more fully into the information-intensive aspects of artifacts and institutions;
- ways to organize the development process that take advantage of its decomposability according to the levels of abstraction of the information being processed; and
- concepts to associate educational institutions and industrial, governmental and non-governmental organizations on the basis of the new needs for research and training in the areas of information-based design planning.

The information age is making much of this possible by contributing to design:

- computing power to generate, store, retrieve, modify and manipulate qualitative information; and
- communication power to present information in appropriate forms wherever it is needed.

The synergy is elemental. Raising the level of awareness of this among design and information professionals is critical to the qualitative development of the information environment.
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ABSTRACT
The thesis of this paper is that design, the purposeful restructuring of information and activity, is an essential competence in the age of information, that it belongs at the center of education as a general discipline, and that a categorical model based on the process of designing affords a basis for structuring and sharing information across disciplines and fields. Seven roles oriented types of information; directional, descriptive, relational, contextual, procedural, empirical and reflective, are identified and interpreted to relate the conventions of scientific disclosure to the process of design and to suggest the potential utility of the model for structuring and applying information.

Keywords
Design, model, disclosure, categories

INTRODUCTION
Design is only now being recognized as a productive discipline capable of giving useful form to information, activity and material in any field. As such, it affords an effective basis for the development of networked systems to support multidisciplinary learning and work, for structuring communication across disciplines and for improving human potential.

The capacity to design – to recognize needs and objectives, gather relevant information, conceptualize and analyze its application, formulate an appropriate plan for a given context, produce the intended outcome, assess its effectiveness, and determine its significance and value – can be applied to anything.

Understood this way, designing is not restricted to any particular domain, like language is to words, math to numbers, or music to sounds. It is a generic process that may be applied to anything where problems need to be solved or purposes met by producing or doing something that is not self-evident or pre-determined.

Designing is central to the organization and application of information in daily life and in all professions. Everyone designs when they purposefully seek objectives that are not well defined. Yet this capacity to think and act in ways that are practical, constructive and fulfilling is often inadequately valued and developed in individuals, organizations and cultures. The issue is how to foster and support the development and use of the human capacity to design in the years ahead.

The thesis of this paper is that design, the purposeful restructuring of information, activity and materials, is a competence needed by everyone in the age of information, that it belongs at the center of education as a general discipline, and that the process of designing affords an effective basis for structuring and sharing information across disciplines and fields that has great potential for improving human capabilities.

WHY IS DESIGNING SIGNIFICANT?
Designing belongs at the center of education, communication and work today because:

1. Design may be applied by anyone to any subject and to problems of any scope or scale, in any context, using any mode of thought, expression or action and any medium or discipline appropriate to the task at hand.

2. The process of designing accommodates individual motivations, interests and abilities in constructive experiences that challenge, frame and engage individual initiatives. Many different points of view are invoked during design and personal styles of thinking and doing emerge naturally while remaining responsive to other styles and events.

3. Designing integrates imagination, critical thinking and responsible action. It teaches how to cope with inadequate information to solve poorly defined problems through conceptual exploration, the acquisition of relevant information and its effective application in a given context to achieve something of value.

4. Designing emphasizes constructive thinking in a given context over factual retention and rote learning. Because design problems may have many different solutions designing requires ongoing definition, representation, and assessment. It is inherently a learning experience arising out of a need to obtain and correctly apply information to achieve goals that may change with knowledge of the problem.
5. Designing links information to experience and learning to doing. It organizes thought and action into productive processes in actual circumstances making them easier to understand, remember and reuse. Skill, competence and self esteem arise naturally through successful design experiences.

6. Designing encourages objective assessment and reflective learning. Its achievements are self evident and provide an empirical basis for learning that is evaluated in terms of the goals guiding design. Success is understood through evaluation of progress and self assessment is necessarily continuous as one works through the issues which confront them.

7. Designing in teams and for others encourages the development of social skill and perspective, including the ability to negotiate, communicate, follow, and lead. One learns ethical and moral values by sharing ideas about what is appropriate and effective in addressing human needs and desires. Emotional satisfaction, sufficiency, goodness, beauty, efficiency, truth, and wisdom are humanistic values directly addressed through the core activities of designing.

8. Designing promotes reflective learning and the growth of knowledge in both individuals and cultures through creative experiences that integrate different aspects of intelligence, knowledge and behavior with knowledge gained from prior experience and social interaction. It requires consideration of people, resources, relationships, contexts, methods, outcomes and values beyond those arising from the immediate problem.

Designing calls on the humanities and the arts to express, communicate and interpret ideas and potentials, on technology to implement them and on science to assess their outcomes. Education based in design can produce an understanding of art, science, technology and the humanities that is integrated, interdisciplinary and humanistic.

**WHY DESIGN TODAY?**

Designing is the key to the intelligent application of information and technology to meet human needs and wants. It is as fundamental to this age of abundant information and almost unlimited technology as scientific method was to the natural history stage of inquiry and the age of industrial development.

This is because designing provides an operational framework through which to formulate, communicate and realize what could exist that is similar to that through which science establishes information regarding what does exist. Just as scientific method and technique provide a common framework for communication that enables the development of scientific knowledge the process of designing can provide the structure needed to support the growth of knowledge about what might improve the present and shape the future.

Designing also provides both the context for a science of the artificial and novel information that requires scientific assessment. Science can not remain focused on explaining natural phenomena, but must also help to determine the appropriate relationships between man, technology and nature as they are developed from abstract representations to physical realities through design. New possibilities must be accompanied by ways to evaluate their consequences before they are realized.

**WHAT MODEL OF DESIGNING?**

What then is the structure of design that might allow it to be a reference for thought and action in any field? How can science be integrated into design to assure the efficacy of design outcomes?

It is proposed that all purposeful systems for using information can be related to a common information structure based on roles within the design process, that this structure is shared with science and can support both creative and empirical activity, and that its application can differentiate as well as relate subject oriented disciplines while supporting interdisciplinary communication and the growth of knowledge.

The generalized information structure that is proposed is related to different kinds of information and the roles they play in the processes of design and science.[2,3] The same core roles are involved whether used to create a poem, a painting, an automobile or a scientific experiment. [4] Consistent reference to these core roles during design can build knowledge and capability in the same way that the pattern of disclosure based on scientific method has helped to establish knowledge in science. Both processes employ the same kinds of information for different purposes; design to create, science to explain. It is this common framework of operational distinctions that afford the opportunity to integrate design and its assessment.

The basic kinds of information used in both science and design and the roles they play in each are characterized as follows:

**Directive Information**

Both science and design require that attention and effort be purposeful and focused toward recognizable goals. Design begins with a recognition of a need or desire to be met. A scientific experiment begins by framing the problem being addressed and establishing the background and purpose of the work.

**Descriptive Information**

Both science and design must identify and describe what is considered. Designing requires identification of the information to be considered and the resources to be employed in creating something new. Scientific reporting always identifies the specific issues, factors and variables being addressed.
Relational Information

Both science and design require the purposeful structuring of information. In designing information and resources are related to objectives through conceptual models which support conjecture and the exploration of possibilities. In scientific disclosure the hypothesis, and rationale underlying the experimental approach must be explained.

Contextual Information

Any discipline depends on its context of application for meaning. Designers must adequately represent the conditions for which a design is developed to those who must understand or use it and in order to assure that it fits the context of use. The circumstances and constraints under which a scientific experiment is conducted must also be described for its results to be understood and replicated.

Procedural Information

Proficiency in both design and science is dependent on effective procedures. In science, the actual sequence, conduct and control of research procedures are reported as the basis for critical review and confirmation. The use of the computer during design now makes it possible to simulate, record, improve and support design procedures which traditionally have been communicated through apprenticeship and rarely documented.

Empirical Information

Achievement in both science and design requires the critical assessment of information directly obtained through the processes involved. The findings that result from scientific research are always documented and subjected to critical review. Evidence for the usability or effectiveness of a design, traditionally available only after a design was physically produced, can now be obtained and evaluated throughout its development via computer based simulations.

Reflective Information

Future potential in any discipline rests on integrating newly acquired knowledge with that from prior experience and from other sources. The scientific researcher always interprets research findings, their implications and significance. To learn from experience the designer must also consider the consequences and implications of what they do.

Different subject orientations, modes of processing, and intelligences are also implied by each type of information. Taken together they provide a generalized framework that is useful for structuring and communicating thought and action in any field.

IMPLEMENTATION OF THE MODEL

The role oriented model of information outlined above has been explored and applied in many contexts. (Burnette, 1969, 1982, 1993A-B, 1994 A-B-C, 1995A) A computer based system has been formulated according to the model and is partially operational as a system to support conceptual design and its assessment through interactive simulations in virtual environments. (Burnette, 1995B)

The model has also been interpreted for teachers and students in a program for Design Based Education K-12 (Burnette, 1993A) and provides the framework for a graduate program organized as an interdisciplinary design team to develop an integrated computer system to support design. (Burnette, 1994B) There are many other interpretations that retain the core meaning of each domain of information in the model.

The seven domains can be used like a language to establish, convey and guide interpretation of information on any subject, at any level and for any purpose by individuals or groups acting informally or through formalized or computerized procedures. They have been interpreted as schema, (Lakoff, 1987) semantic dimensions, (Burnette, 1994A) sub-disciplines, (Burnette, 1994C) forms of intelligence (Gardner, 1983; Burnette, 1993A) and educational objectives. (Bloom, 1956; Burnette, 1993A)

No matter in which context they are translated the core types of information contribute to a complete expression at some level of consideration in a manner analogous to the way the components of a sentence (i.e. noun, verb, adverb etc.) contribute to the expression of thought. The roles they manifest also provide a basis for rationalizing the activities that occur in each domain, for representing, coordinating and linking information among domains and for analyzing the content of communication.

In summary, the intent of the proposed model is to support all aspects of designing through one information structure that can be understood and applied by anyone in any discipline.

1. The structure of the system is based on seven kinds of information each supporting a particular role in the design process.
2. These categories, which fall within the conventional limits of short term memory, provide a useful, easily remembered reference for organizing thought and expression and interpreting the expressions of others.
3. In the computer system based on the model each of the activities defining a primary role is implemented through software tools that facilitate each activity.

CONCLUDING NOTE

A unifying framework for future learning and work can not depend simply on technology. It will depend on seeing similarities as well as differences in disciplines, on giving form to ideas and determining if the forms are useful for the purposes intended. It will depend on designing!
Increased competence in designing will itself depend on better ways to model, communicate and employ thought and action to create useful and valuable outcomes. Designing must be explained through conceptual models of creative activity; not just manifested through its outcomes.

The role oriented information structure outlined above has the capacity to both represent and facilitate design activity. It can be used to organize information to create what does not yet exist as well as to explain what does. It is a potent tool for the information age.

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Achieving the Ten Year Design Goal:  
Start at 2006 and Work Backward

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ABSTRACT  
Moving design into the Information Age requires that certain processes and programs be put into place now. This paper provides ideas, insight and opportunities for those who are involved in reconfiguring design for the Information Age.

Keywords  
Design, Information Age, technology, interdisciplinary teams

INTRODUCTION  
Ten years is not far off, especially when we consider what needs to be done to reach our goals for design in the Information Age. If we start at the year 2006 and work backward, it gives us an idea for what we need to begin to put in place today. In this very brief overview I will touch upon the scope of the players, the opportunities for the design profession, the technology that is currently in place to lead us into the future, and recommendations for achieving results for design in the Information Age.

SCOPE OF PLAYERS  
It’s not just us anymore. The foundation of future design studies is being laid today by universities, state governments, students, the design industry, design educators, and other disciplines such as Communication, Engineering, Library Science, Architecture, Computer Science and other arts and sciences. Universities will continue to have budget cuts and search for ways to offer more to a wider range of students. State governments are having a direct hand in which graduate programs are supported throughout the state system.

Design students are asking for skills to make them more marketable. The design industry is saying the universities are not preparing students for the available positions. Design educators are filling the curriculum with added requirements to meet many demands. Other disciplines are perfecting their models and offering them to the design disciplines. In spite of the pressures, demands, offers, changes and delays, this increase in the number of players in the design community allows for opportunities to expand the design world further, think in new ways, and have people and technologies available to us that are not available.

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Many classroom situations have barely progressed beyond the lecture supported by overhead transparencies.

Goals for future design education in relation to technology should include the availability of individuals and universities accessible to us from across the wires, enhanced course content, and technologically assisted research. Listed below are recommended key areas of technological development for the future of design education:

- **Multi-location and Multi-disciplinary team members**
  People, not technology, will promote ideas. In the future, a professor from one university may team with a professor from another university to run interdisciplinary courses on a regular basis. This is not a new concept but the number of participants in this practice is limited. The future will provide us with better telecommunications possibilities, allowing for easier implementation of discussion procedures and imaging techniques.

Technology will allow physical spaces to be reconfigured as telecommunications opportunities arise. Universities today are evaluating budgets in relation to either increasing services or repairing physical spaces (Acker, 1995). Limited funds help to force this “either/or” situation. Other fiscal trends and economic pressures (or opportunities) will lead to design education situations whereby individuals and groups from different locations, in different disciplines, work together as a team members. These members may never meet in person. These telecommunication teams may indirectly provide for a wealth of space to be used in other ways. Businesses may want to take advantage of the university setting, wealth of interns and education and take up residence in campus buildings. Software training companies may trade university space for training of students and staff.

- **Visually enhanced content in the design learning environment will be available.**
  Virtual simulation, virtual video, three-dimensional imaging, visual storage, recall and creation systems will be refined and enhanced to assist designers, design educators and others in the classroom. The opportunities to create visual content, as well as become involved in the refinement and development of these software tools offer great opportunities to designers, design educators and students.

Traditional teaching roles may change. The roles of the instructor are many: creating and preparing content, delivering the content, advising students, evaluating students and service roles. The specialization of the various teaching roles may emerge in the future (Massey & Zemsky, 1995). Some instructors may wish to prepare content for several other instructors. Some instructors may want to be in the classroom only. Some instructors may want to take on more of an advising or research role.

Opportunities for designers to prepare creative concepts in a highly intelligent, highly accessible environment is in our near future. Other disciplines will become even more involved in the creative and evaluative process. Design research and practices will continue to alter through technology. As a result, designers, and design educators of tomorrow will need to embrace teamwork, research and technology in a more profound way, and possibly encourage specialization within the teaching framework.

- **Technologically assisted design information gathering and applied research through the use of globally accessible intelligent databases will be available.**
  The increase of intelligent databases that simulate natural forces in nature will be available to designers on a widespread level in future years. The effects of fire, chemicals, wind, touch, plantlife, light and a host of other natural forces and artifacts can be assessed in relation to the design of products and space. The use of three-dimensional computer models in conjunction with intelligent databases may allow the designer to enhance the ideation and evaluation stages of the design process.

Universities linked for global communication systems will allow design researchers to access texts, images, models and users. Open forums for the public, in relation to product design is a way for daily feedback and evaluation of projects to occur. Individuals, as well as corporations, could have internet access to particular design projects, especially when the design of public works is involved.

Designers who prepare concepts for users in foreign countries will have access to national trend information, as well as cultural preferences and legal issues from that particular country. Current information about color preferences, daily habits and needs of individuals from other countries will assist the designer in the research and evaluation phases of the design process. Other disciplines working on the same design project may access international information that will impact the concepts chosen for production.

Research will be conducted between multi-disciplinary groups from various universities and corporations. Research methodology, as well as evaluation techniques, will be modified and assisted through the coming technologies in telecommunication.

**RECOMMENDATIONS FOR ACTION**
We are at the junction of what we do have that we might utilize and what we really need that is not yet created. Just as we look at the white space that helps us to define an image, we can look outside of our design profession to see what is needed to help define and ease our work. Over the next ten years, we can achieve the goals of enhanced curriculum, enhanced teams and enhanced technology if we begin to put a foundation in place today. We can approach the goals presented in this paper through the following recommendations:
• Form alliances with other universities and individuals to offer inter- and multi-disciplinary courses.
Departments should assess strengths and weaknesses they have today and look see what other universities and individuals can offer them to fill in their knowledge or technology gap. Design departments can begin to form courses between universities and individuals. In some cases it is easier to list courses at two separate universities than from within the same university. Each university gets credit for their own enrollments and each university can offer their students access to individuals, methods and practices not otherwise available.

• Prepare to provide an enhanced interdisciplinary design studio experience with the use of interactive technologies.
Current classes could take advantage of the technologies available today. Put in place support for faculty and students (Schneiderman, 1995) to produce interactive learning modules and materials that can become available for other universities to use. Departments that produce interactive projects can use the projects as a source of funds from students, businesses and other universities.

• Preserve current content for a library of images, interviews, videos, discussions, debates, examples, etc.
Interactive media requires an enormous amount of imagery and content. Purchasing images and text for extensive classroom use is prohibitive. In order to amass content for interactive work which contains videos or sound of processes, interviews, examples, discussions, events, etc., we can document as much as we can as often as we can.
We need to preserve our history in a rich way, one that allows a student to see for himself or herself, not always through the interpretation of a lecturer or textbook.

• Support university continuing education courses.
Universities, as well as design departments, are facing a trend of lifelong learners (Dolence & Norris, 1995). Continuing education classes can be used to reach those people who need to expand their knowledge base or become adept at the new technologies. The continuing courses are a way to bring in other courses that may not always fit into a specific curriculum or discipline.

• Reconfigure departments to reflect desired job tasks.
Faculty may want to work differently than they have been working. Some faculty may feel more adept at teaching technology-driven design assignments than others. Some faculty would rather pull content together in a meaningful and rich way for another faculty member to deliver in the classroom. These are new ways of looking at a system that has been in place for hundreds of years.

• Enhance content for all disciplines working on the same task.
Visually enhanced content can assist learning. The business and engineering students involved in an interdisciplinary course could greatly benefit from supplemental interactive materials on the field of design, rather than being placed in a studio setting that is "trial by fire". The design students could also benefit from enhanced content from other disciplines before approaching a joint task.

• Partner with businesses now.
Businesses are in need of interns, as well as training for their own staff. Approach businesses for two-way training. Students can train in the professions and the professionals can train in the classroom on the new technologies.

CONCLUSIONS
We need to take advantage of the technology that is currently available, assess its use for the classroom, practice and research, and push for support for faculty and student training. We need to provide enhanced content through interactive media in our classrooms for all students. We need to evaluate our departments' strengths and weaknesses and partner with individuals and universities. We need to start at the year 2006 and work backwards for the plan to achieve our goals in a meaningful way.

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Design 2006: The Future of Designing Products and Technology for People with Disabilities

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ABSTRACT
This white paper explores the future of designing for people with disabilities and the implications for technology development and design professions as the population with disabilities increases. The paper contains the following considerations: 1) identification of the people with disabilities and the implications for designing products and technology; 2) the relationship between disabilities, vocations and technology; 3) product and technological developments that are likely responses to the needs of people with disability by the year 2006; and, implications for the role of designer and the education of design professions. The main thesis of this paper is that technology should enable and empower independent action on the part of people with disability by reducing the cost of dependency.

Keywords
Disabilities, products, technology, design, designer, dependency/independence.

UNDERSTANDING DISABILITIES
A critical dimension of designing for people with disabilities is understanding who they are and what their characteristics are like. Frequently, very large numbers of people are cited as living with disabilities - and some of those numbers will be cited in this paper. The full picture, however, is more complex than homogenizing all disabilities into a single number as if they represented a monolithic market. That approach is misleading and counterproductive. Disability has been defined in the 1994 Statistical Abstracts of the United States (US Bureau of the Census, 1994) as:

"...reduced ability to perform tasks one would normally do at a given stage in life."

"...difficulty with mobility, manipulation (and/or) communication."

Michael Callahan, Project Director, UCPCA
Choice Access Project, January 1996
(Callahan and Angle, 1996)

Certainly other definitions exist and one must question the specific use of terminology in this definition. Human performance is variable over a lifetime and what is "normal" within the context of specific age groupings is difficult to define. Both characteristics are more diverse in their range as people age - without any context of disability. If the standard utilized in the Americans with Disabilities Act is used as a benchmark (Lortz, 1994), then people reporting that they are living with a disability is sufficient to designate that person as disabled. Thus, the actual numbers of disabilities corresponds to the definition of the term. Under the law, the Americans with Disabilities Act states that if a person declares themselves as having a disability, that person is disabled. A paraplegic graduate student at Georgia Tech was overheard to say that, "...a person with a disability is someone who has not learned to use all of their abilities." Accepting that definition, 100% of the human population is living with some degree of disability.

Since no universal definition of the term "people with disability" exists. It is at least expedient to accept the U.S. government's definition since their description of population statistics results in allocations of funding for services. According to the census data, in 1991/92, just after the 1990 census data collection, from a population of 251.8 million, 48.6 million or 19.3% of the total population were living with some level of disability. Nearly half, 24.1 million were listed as having a "severe" disability and 24.8 were listed as "not severe." These disabilities are all physiological related to sensory modality deficits, mobility, and performance of tasks related to activities of daily living.

In 1995 the population has been projected to be 263.4 million. Conservatively, 50.8 million of that population would be people living with disabilities. Projecting forward, populations between the ages of 55 and 85+ will virtually double and the percentage of people with disabilities may rise from 21.4% to 28% or, as another conservative estimate, 94.7 million people. (US Bureau of the Census, 1994) If accidents, injuries and violent crimes continue to increase in the total population, the total number of disabilities is likely to be higher with greater numbers among the most severely disabled. In turn, these severely disable people will have an extended life span - virtually the normal life span - and this factor will likely expand the numbers even more. Work related injuries are another important component of the disability picture and constitute a critical component of lost hours/days of work and cost to industry and society.

The year 2006 is not quite the midpoint on the way to a major demographic shifting in the population. By that year, the
nation should realize the dimensions of the shifting by virtue of the number of older Americans and how many people with disabilities there will be. 54.7 million people or nearly 21% of the population are now over the age of 55. Around 2006, 65.9 million or nearly 23% will be over 55. Two decades later, over 30% of the population or just over 102 million people will be over 55 (US Bureau of the Census, 1994).

High level or spinal cord injuries that result in the most severe of all disabilities including paraplegia and quadriplegia are the result of: 1) automobile accidents (50%), 2) falls and falling objects, 3) sports related injuries with pool/diving related accidents accounting for over 60% of all sports related injuries, 4) violence related injuries (12 to 18%). 226,000 people are disabled through spinal cord injury with 110,000 living quadriplegics. 82% of the injuries occur to males with 65.9% of these injuries occurring between the ages of 16 and 30. The prognosis of post injury survival is 17 to 25 years-improving recently to a potential of 30 to 40 years. (Stover and Fine, 1986)

Another pervasive issue is that of “hidden disabilities.” Hidden disabilities, again, may not result in physiological changes that alter performance. They are more likely to result in psychological changes that affect behavior and attitude toward job or task related performance. Or, there is a significant physiological learning disability that must be diagnosed and understood by both the individual with the disability and institutions that seek to provide education or utilize the services of that individual. In 1992, nearly 500,000 people were receiving treatment as substance abusers (US Census Bureau, 1994). 10,000,000 Americans are diagnosed as suffering clinical depression (US Census Bureau, 1994). As of the end of 1994, 50% of all ADA claims are now disabilities related to stress in the workplace- not a disability listed in the Census Data.

Illiteracy is the most pervasive disability in the American population with 1 in 4 adults, or 52.3 million people functionally illiterate (reading below the fourth grade level). Out of this population, only 8% is accessing literacy training programs (Beber, 1991; Pugsley, 1990). In other words, 25% of the American adult population over 18 years cannot fill out a job application, obtain a driver’s license, fill out a tax return-much less work at jobs requiring reading comprehension. Computers have significant advantages in assisting the development of reading skills but to use the computer one must be computer literate at some basic level as well. It is possible that by the turn of the century, computer illiteracy may be considered a form of disability.

DISABILITIES, VOCATIONS AND TECHNOLOGY

While the numbers are impressive, as stated, they are also deceptive. 50 million people living with disabilities is not a single agglomerated market. What we also must see in these numbers is diversity. There is diversity among disabilities and there are individuals with combinations of disabilities. Some disabilities are physiological and others are psycho/social. The greater the number of disabilities present in a single individual, the more unique that person becomes. Many people with disabilities constitute a market of one person.

Various philosophic approaches to designing for people with disabilities have been taken that date back to Selwyn Goldsmith’s (1967) seminal work on barrier free design generated for Royal Institute of British Architects before any other standards were available elsewhere in the world. The effort to create a national standard came later in the United States with the work to provide modifications to the ANSI A117.1A standards to incorporate standards for barrier free design. Barrier free design, however, is architectural and has very limited effect upon the usability of products and product technology. Architectural standards respond to issues of the macro-environment. In the late 70s and early 1980s it was realized that an association of products and their technologies made up a micro-environment (Koncelik, 1982) and that these associations of products had a profound impact upon aging people and people with disabilities. This approach was amplified in publications by James Pirkl (1990). Pirkl called for more inclusive design of consumer products that he termed Transgenerational Design. However, inclusive products do not deal with exclusive situations of disability and the design community- that group that works with manufacturing clients- has left the more severe levels of disability unattended through applications of design, product and technology precisely because the manufacturing community cannot deal with the uniquenesses inherent in the population of severely disabled people.

The image of disability is heterogeneity not homogeneity. Disabilities diversify the population mitigating against uniform descriptions of characteristics. The higher the level of disability the more specialized or customized the technological and product response will be to meet critical needs. Some individuals have levels of disability that create a market of one. Conversely, the lower the level of disability the more common it will be and the greater the number of people enduring that disability. Sensory modality change in hearing and vision with age, for example is common to a greater or lesser degree for the entire population over the age of 55. However, again according to census data (US Census Bureau, 1994), only 10.8% of the 13.1 million people using assistive technology use wheelchairs of all kinds. This is a viable market for wheelchair manufacturing (not including temporary use of wheelchairs) but it is an industry that relies upon limited production runs and low volume production methods resulting in extremely high costs for products to the consumer in need.

Various retirement and insurance programs such as are reporting a shifting away from the old axiom of “The three legged stool” of retirement (social security, pensions and savings) to a new model, a four legged stool. This model incorporates the previous three legs but now includes work as a
Some retirement programs are choosing to see this phenomenon as a failure of the concept of full retirement, but younger retirees with a potential for 30 years of additional productivity and no obstruction to their working owing to the elimination of mandatory retirement law may see things differently. Working longer may also mean working with a disability- and having the protection to continue working under the law.

David Birch (1988) has reported that the overwhelming number of jobs created in America will be with small business with 90% of these jobs among companies of 9 employees or less. For the most part, job creation will take place in businesses that may not be subject to ADA regulation (15 employees and above). There is gradual and increasing amount of work out of home offices- occasionally supported by some medium sized and large companies. However, the greatest number of work from the home situations are self employed individuals providing services.

Work for remuneration is different from jobs for pay. Federal program for re-training of displaced workers, minorities, the disadvantaged and people with disabilities emphasize jobs as a result of training or retraining. Federal guidelines under Title I, II, and III contracts and grants for training providers stipulate not only employment as a mandatory resultant, but also specified levels of income. The failure of a training provider to attain employment for all individuals trained or re-trained at the specified income level is deemed “unsupportable” and can result in discontinuation of contracts. The viability and long term effectiveness of this approach is questionable. There is sufficient information available to everyone at this time demonstrating that vocationalism is becoming volatile, ephemeral, subject to change and highly individualized. The traditional employer/employee construct of work is fading into a vague mélange of networked and variable work for pay situations.

The experience of the many centers around the country in working with people with disabilities has shown that motivation to work is the critical indicator of success. Regardless of the level of disability, motivation among individuals will carry them through to any goal and they will not be deterred by any physiological obstacle. It is also an important experience that those individuals who have suffered psychological disabilities, such as substance abusers, or those who have not learned such rudimentary skills as reading and writing are at a far greater disadvantage with higher emotional and psychological obstacles to overcome than those individuals who are physically challenged. Even so, only 15% of all quadriplegic individuals are working. Most with high injury levels cannot work. As a testament to issues of motivation, only 8% of all functionally illiterate adults are enrolled in literacy training programs (Pugsley, 1990) and the hardest to recruit are functionally illiterate people over the age of 65.

It seems appropriate to develop a view of the issue of vocations as part of a larger effort to reduce the cost of disabilities- with vocationalism only part of the effort to be directed at cost reduction. A far more cogent approach to the problem would be to emphasize increasing levels of accomplishment with technological assistance in the following hierarchy of human endeavors: 1) Activities of Daily Living, 2) Environmental Accessibility, 3) Quality of Life, 4) Educational Involvement, and 5) Vocational Pursuits. There is a progressive and linear relationship between these five levels of independence. One naturally leads to the other and one cannot be accomplished without the other. As individuals accomplish each endeavor, independence and self reliance increases and the cost of supporting the individual decreases.

Decreasing the cost of support to people with disabilities must become the major overall goal of support through technology and product development. Is technology a critical support to vocational pursuit among people with disabilities? It is possibly critical, but not always. Technology is usually critical in achieving the linear and progressive development of independence. Indeed, because the goals broaden the possibilities for technological innovation, the potential for development of multiple technological responses should increase dramatically.

In-house research shows approximately 80% of all the products and technologies provided by the Center for Rehabilitation Technology at the Georgia Institute of Technology to people with disabilities over the past decade have been computers and related computer technology. It is evident that computers are a key to developing independence of action and potential development of educational pursuits- and eventually vocational outlets. The largest number of “clients” of CRT are referrals from the Georgia State Division of Rehabilitation Services. These individuals, many with severe disabilities, are all supposed to be rehabilitating and re-training toward the goal of employment. However, not all of these clients reach that goal nor did they intend to from the beginning. As clients, many remain clients for a very long period of time, accessing CRT and various technological supports over time.

While the early history of CRT witnessed virtually 100% placements and 80% retention of people with disabilities accessing services, those statistics have changed over time. The change is due to many factors. Support of this kind was not available either in the State of Georgia or nationally just two decades ago. This essentially backlogged many people with disabilities who were highly motivated to work. As time has passed, fewer of the clients are either able to relinquish medical benefits they would forfeit by taking a job, are interested in pursuits other than work (education) or require many other related services in order to move them toward employment. The experiences within the approximately 82 similar centers nationally would likely provide similar information. Technology and training must be combined with motivational sup-
port, job interview skills and many other services in order to move any individual who is the traditional client of federal and state agency services to vocations.

POTENTIAL PRODUCT AND TECHNOLOGIES IN 2006 FOR PEOPLE WITH DISABILITIES

Knowing who the people are and their characteristics is the first essential step in identifying the targets for product and technological development. The opportunities for product development are quite broad considering the number of issues of human performance and the overall goals to be achieved in the application and utilization of technology.

The first step in achieving meaningful results with product and technology development is to create strategies and resultant technologies that proactively reduce the incidence of injury as well as ameliorate the problems of injury after they occur. This means, first, that an emphasis must be placed upon development of technologies that make the man made environment safer to use; second, that warn or inform about a dangerous environment; and, third, help to rehabilitate and sustain human life and lifestyle when there has been a system or human failure.

Another important considerations is the utilization of the flexibility of modern production methods to ensure the highest variability of product offering. Looking for mass market targets will not effectively change the lives of the populations with the highest level of disability. There must be acceptance of a service system that produces customized technology for those individuals who will not have their needs met by off-the-shelf mass produced products. Attempting to commercialize and maintain individualized products will be difficult and costly and time consuming. The rehabilitation centers, typically affiliated with research universities, are the most effective means at the disposal of the nation and its variable system of health care to assess needs, provide the technology and maintain both the hardware and the person utilizing it.

The future of computing is likely to be driven by the rapid advances in reducing the size of components, increasing the input methods (interface) and making the technology responsive to voice and other forms of actuation. The box and screen form of desk top computer with its stand alone, space consuming footprint and keyboard/mouse interaction will be around for some time to come. However, the hidden computer that becomes part of another product or part of clothing or part of the human anatomy will present new and exciting possibilities for people with disabilities. Smaller, lighter, faster and smarter computers expand the range of users among people with disabilities and the aging. Eg.: wearable computers as controllers for other devices, bar code readers, voice sampling for directed hearing prostheses.

Focus attention upon variation of input modality: voice actuation, gross motor actuation, sip and puff, template overlays for keyboards, infra-red eye blink menu selection. Computers will become processors of information enabling intellectual and physical activity rather than desktop devices simulating alternatives to television.

Envision lightweight wearable computers as controllers that are worn by older users with hearing loss. Miniature microphones sample voices and focus upon specific persons in conversation. Background noise is automatically expunged in real time from the range of sounds and filtered as well as amplified and enhanced for the user. Wheelchair (motorized and manual) born computers that direct chairs away from dangerous terrain or stop and alter course of the chair through optical sensors. Holographic bar code readers that sample markers placed strategically for the blind. Information is provided to wearable computers that read and speak through a synthesized voice that direct the user through complex environments and keep them safe. Another step would be to use satellite positioning to locate a blind person and guide them literally step by step to a destination.

There is intense interest in electro-stimulation as either a method for developing exercise for severely disabled individuals or eventually as a method for rebuilding their capacity to regain use of their bodies. The Miami Project in Miami, Florida has set itself the mission of “curing” paralysis. Scientists, medical professionals and engineers are working in teams to develop high technology responses to this prodigious goal. Going further, there is considerable interest in tissue regeneration; a problem that requires as much engineering knowledge and research as it does medical and physiological knowledge. There is also interest in computer chip implants to regain control of the body through a simulated rebuilding of the nervous system and many other areas of development that were the province of science fiction only 20 years ago.

THE ROLE OF DESIGNER IN 2006

It is becoming less clear as to who the designer is especially dealing with complex problem solving in the area of rehabilitation technology- nor should it matter very much. No specific discipline seems to have a lock on all knowledge necessary to engage the issues that disabilities present and the emergence of the team approach has become the order of things. The basement inventor or the singular research scientist buried in a lab alone is not a viable construct for achieving solutions to critical human problems principally because it is not possible to remove the design process from the mainstream of information flow. The engineer requires medical knowledge if not expertise to approach problems of designing for disability. Industrial designers now work more effectively when they steep themselves in manufacturing processes and materials development, and so on.

Educating the designer- regardless of whether the educational base is scientific or artistic- has become an ambiguous proposition. Finally, now in the 90s, the realization has emerged that designing is not a research or analytical process. Like-
wise, product development to meet critical human needs is not principally an aesthetic issue. While the logical response seems to be an amalgamation of the two approaches to designing, this is far more complicated than it first seems. In the final analysis, reformulating the education of the engineer or the industrial designer does not only require fusing design methodology with scientific method (difficult in and of itself) it must also be combined with the entrepreneurial construct of business and marketing and, with regard to rehabilitation technology, a strong base in human physiology, anatomy, gerontology and medicine. Hence, the emphasis on the team approach when technology development is engaged and also the emphasis on graduate education to enable individuals the knowledge base to pursue deeply complex human and technological problems.

CONCLUSIONS
It is a fascinating proposition to select a point in time ten years out from today to speculate upon the issues confronting design professions in human and technological terms. A pattern of development is discernable from all that is known through the accumulation of information about populations in this nation and all other industrial nations. Focusing upon problems of human health and especially disabilities, there will be steady growth in both the proportion and total number of aging individuals, steady growth in the preponderance of disabilities among the general population of all kinds and at all levels. Not only will there be more people with disability, those living with disability- regardless of severity- will live longer lives. By 2006, the world will only be at the beginning of the experience of living with substantial numbers of aging and people with disabilities. By that time, design professions should have realized- fully- that these populations and the issues they present to us are and will be a major focus of design attention.

There is a direct relationship between issues of disability and cost to the national treasury. The money available and the resources required are likely to become more disparate over time- but the costs will still be there. A major thrust of all policy formulation and the direction of technological development must be the reduction of costs of care for individuals, families, government, industry and institutions. Vocationalism is only part of the answer in reducing these costs. Jobs and employment will not be a complete answer to changing the picture of dependency and cost. Increasing independence, enabling and empowering people with disability to gain control over their own lives and promoting and sustaining educational pursuits is also part of the picture. Experience and available information demonstrate that only a small proportion of the most severely disabled will become employed. ADA has been an effective means for developing greater environmental accessibility, but it has been less effective at increasing employment among people with disabilities. Yet, it is also likely that those among us who are either aging or becoming disabled both physically and psychologically who are employed are likely to continue their employment- and the law protects their right to sustain that employment.

The thrust of rehabilitation technology is using and creating technology to increase and sustain independence among people at varying levels of disability. The computer, in all of its forms, has become a major technological support for people with disabilities. The potential of the technology is increasing the opportunities for developing independence among this population and thereby reducing the costs of care and increasing the potential for educational and eventual pursuit of employment.

Implementation of new technologies is not dependent upon a single profession. Team approaches have become the order of things in design methodology. Identification of who specifically is a designer has become more ambiguous- and less important than resulting innovation and workable solutions to problems. In fusing engineering education with design and design education with greater scientific content may prove useful, but are not the only propositions that are viable pedagogical directions. Education is likely to become more fragmentary within professions and between professions. Disassociation of degree programs from vocations is aiding and abetting the heterogeneity of educational approaches- likely to continue well through 2006 and into the foreseeable future.

REFERENCES


A Plea to our “Funding” Fathers:  
A Collaborative Model in Support of Design

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ABSTRACT
Graphic design education programs are in need of external funding to support the high cost of technology and the research interests of its faculty and students. At the same time, the process of design is becoming central to many other disciplines that strive to communicate over the fast growing electronic channels of today's global network. This paper proposes a model for funding collaboration between designers and the researchers of new or previously funded projects who rely on visual communication to enhance and further their research agendas. In this multidisciplinary relationship, designers would profit from the influx of grant dollars and access to shared resources. The other researchers would benefit from design expertise throughout an entire project—from its inception to its final outcome.

Keywords  
Graphic design, design, multidisciplinary, funding, new media, research, technology

In the past, the applied field of graphic design education, with its commercial component, used to be considered the ignoble member of the fine arts faculty. However, today, as information becomes the currency of communication, graphic design, with its ability to inform, educate, persuade and entertain is being elevated to a much more prominent position in art and design departments and in institutes of higher learning. The discipline has come of age as the Internet takes on a graphical interface and its users best understand information when it is visually translated and modeled. No longer is graphic design a lonely entity—static and mired in the antiquated conventions of print. Today, graphic design is a dynamic art form that weaves content and context with image, type, motion, and sound. This new paradigm melds both two-dimensional and three-dimensional design disciplines together to create an multifaceted, communication hybrid aptly called “design.”

Design education programs have proliferated and grown to accommodate and to serve the employment demands of the professional community. Business and industry require designers to be both conceptually strong and computer literate. Organizations and industries such as entertainment, communication, retailing, government, education, medicine, science and business recruit designers to fill positions that require not only print-related skills but knowledge and practice in animation, computer-based training, multimedia, WWW design and information visualization. At the same time, the process of design is becoming central to many other disciplines that strive to communicate over the fast growing electronic channels of today’s global network. The designer’s role in new media is diverse and ever changing. A designer is responsible for many aspects of organization and visual support for a project including mapping the hierarchical organization of the information infrastructure, developing a consistent overall look, designing a framework to maintain visual clarity, specifying a typographical style and format, enhancing the navigational schema and creating the artwork required to illustrate the program’s varied concepts. As a result, academic units in the sciences, humanities, business, law, medicine, agriculture and the performing arts are requiring their students to enroll in design courses so that they might be competitive as leaders in the visually conceptualized world of communication and cyberspace.

Today, new technology is no longer a luxury but a necessity in design education. Design programs worldwide are scrambling to upgrade classrooms full of drafting tables to laboratories loaded with computers. It is not unusual for students to decide where to attend college based on the hardware and software inventories. However, new equipment and software purchases and their upgrades, network connectivity, facility management, maintenance, security and personnel staffing are expensive and require the expertise of lab managers and technicians to run efficiently. Furthermore, design programs traditionally are underfunded by upper administration and do not have the infrastructure to compete successfully for external funding. As a result, many art and design departments have been forced to support their programs in makeshift ways. The less fortunate programs are forced to refit classrooms with one-time moneys or hand-me-down hardware. Subsequently, faculty and users can do little when the facility falls into disrepair and obsolescence. Some programs share lab space with better funded counterparts but then they must fight for scheduling and for a voice in decision making. In other cases, the university’s central computing division provides access to general lab sites. This arrangement often does not serve design programs well because their student’s computing needs are so much more power intensive and high-end than the standard requirements of the general university community. Unfortunately, there still tends to be that misun-
derstanding in higher administration that art programs have only minimal computing requirements.

The more fortunate design programs, often located at the first tier universities and private colleges and institutes, have backing from private endowments or their development offices and faculty have been successful in soliciting external support in the form of industry partnerships and grants from foundations and government funded programs. Some institutions even have hired lobbyists to canvass the legislature. Unfortunately, external funding opportunities are becoming even more scarce as government funding, especially for the arts, is drying up, industry is downsizing and competition for grants among educators is increasing. I even sensed resentment at the design@2006.information.edu workshop from the academics who traditionally rely on NSF funding and other external funding sources to support their programs and individual research. In informal discussions, some perceived “us designers” as parasitic in our quest to ride the shirttails of financially solvent researchers.

If design education is to flourish it must be better funded. Programs can no longer make do with have-been technologies to educate a generation of bright students who demand more and deserve better. One option is to align it more closely with affluent disciplines such as science and engineering. We might be in a better position to attract funding but in the rush to conform to the NSF style of funding guidelines we run the risk of compromising our artistic perspective and visual integrity.

A better option is to position design to serve as an integral component in interdisciplinary relationships between disciplines that rely on visual communication to enhance and further their research agendas. In this relationship, design programs would profit from the influx of grant dollars and access to shared resources. The other disciplines would benefit from design expertise throughout an entire project—from its inception to its final outcome. A university with its weave of disciplines, direct access to knowledge, research freedom, computing power and wealth of bright, young minds, would serve as the ideal incubator of these new relationships. As the year 2006 nears, the most successful partnerships will take place at universities that have totally reconfigured traditional instructional hierarchies so that disciplines can work in a less constrained and more interdisciplinary fashion. In fact, interdisciplinary education need not be limited to on-campus exchange, since distance learning, the Internet, interactive technologies and satellite communication are close to delivering a seamless and global virtual education system.

While academia is realigning its academic disciplines and shifting the design paradigm, government grant programs, like the National Science Foundation, will have to redefine and update their submission guidelines. New guidelines should include a multidisciplinary component that integrates design expertise with scientific and other discipline-based endeavor. To further stimulate interaction, select funding applications should require the inclusion of a visual communication expert. This is not a new model. In the early nineties, government and industry increased computer literacy in K-12 education by releasing a series of funding opportunities that mandated K-12 and higher education partnerships. In order for this to prove successful, granting agencies will have to provide individuals who are used to working alone with the skills and impetus to work on teams. To this end, I have diagrammed a Funding Collaboration Model, designed to promote multidisciplinary interaction between designers and a diverse and flexible group of contributors (Figure 1).

As the year 2006 nears all parties must be fluent in a new, conceptually based language in order to effectively construct fresh scenarios for interaction. This means that disciplines can no longer conduct research within a design void. The synthesis of information translated into words, images, motion, sound, touch and smell will constitute successful design, and funding to support this interdisciplinary focus will be essential.

This paper evolved out of discussions with Douglass Campbell, Elizabeth Dykstra-Erickson, Frank Galuszka, Klaus Krippendorff and Elizabeth Sanders during the design@2006.information.edu workshop, in Raleigh NC, February 29 - March 3, 1996.
FUNDING COLLABORATION MODEL

for public and private funding agencies

A proposal to fund a program that seeds visual design expertise and other required talents and skills into preexisting or specially funded research projects. The projects best served by this program would be those that incorporated new media and required the design of information.

External experts
A select group of experts that interact with the teams when special expertise is required. Experts can be cycled in from previous Collaboration Teams.

Collaboration Team
The funding agency seeds a team of innovative new technologists to collaborate on a funded project that requires design expertise. In return, the members of the funded project agree to serve on a future Collaboration Team.

The objectives of this symbiotic relationship are to provide funded projects with access to visual design expertise and thus improve team dynamics and the quality of the project outcome. In addition, design educators would have entree into funded research cycles.

The Collaboration Team interacts and shares ideas with the project team by facilitating workshops, providing specialized consulting, working directly on the team and/or using the Virtual Space WWM network to deliver resources and provide other services.

Project Team
This group is comprised of preexisting or specially funded researchers that have a need to incorporate new media and the design of information into their projects.

Denotes funding nodes in the proposal that would require financial support from the funding agency.
Exploring the Unrealized Potential of Computer-Aided Drafting

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ABSTRACT
Despite huge investments by vendors and users, CAD productivity remains disappointing. Our analysis of real-world CAD usage shows that even after many years of experience, users tend to use suboptimal strategies to perform complex CAD tasks. Additionally, some of these strategies have a marked resemblance to manual drafting techniques. Although this phenomenon has been previously reported, this paper explores explanations for its causes and persistence. We argue that the strategic knowledge to use CAD effectively is neither defined nor explicitly taught. In the absence of a well-formed strategy, users often develop a synthetic mental model of CAD containing a mixture of manual and CAD methods. As these suboptimal strategies do not necessarily prevent users from producing clean, accurate drawings, the inefficiencies tend to remain unrecognized and users have little motivation to develop better strategies. To reverse this situation we recommend that the strategic knowledge to use CAD effectively should be made explicit and provided early in training. We use our analysis to begin the process of making this strategic knowledge explicit. We conclude by discussing the ramifications of this research in training as well as in the development of future computer aids for drawing and design.

Keywords  
CAD, Task Decomposition, Learning.

INTRODUCTION
Productivity increases through the use of computers have been negligible or difficult to achieve in various application domains. The huge investments in the computer revolution, in general, have not paid off in terms of productivity growth (Strassman, 1990), a phenomenon that is commonly referred to as the productivity puzzle. While phase one computers, designed to automate tasks requiring mathematical calculations have had impressive successes, phase two computers designed to augment human capabilities typically have shown disappointing results (Landauer, 1995). Productivity in firms using Computer-Aided Drafting (CAD) systems does not differ much from this general picture. Firms that have used their system for one year report productivity increases of only 5% and typically do not report the maximum productivity growth until they have worked with CAD for five years (PSJM, 1994).

The few laboratory and field studies on CAD usage that are available present a dismal picture. Bietz et al. (1990) found that mechanical engineering students who had passed a CAD course produce better and more complete drawings with less effort using paper and pencil than on a CAD system. Luczak et al. (1991) studied 43 subjects using 11 CAD systems in 11 factories. They found that even when the subjects were highly trained, the high complexity of the commands (due to many input parameters, restrictions, and requirements) led to low performance, reduced creativity, frictions, and frustrations. Finally, Majchrzak (1990) found no improvement in the performance of 25 engineers and 60 drafters using CAD systems in comparison to non-CAD users.

In order to understand the problems faced by CAD users, we observed and recorded professional architects using a CAD system in their natural environment (Bhavani et al, in press). We begin by analyzing an example of suboptimal CAD usage from those real-world data in addition to another example from a study by Lang et al. (1991). These examples will demonstrate that the efficient use of CAD is dependent on the use of strategies that take advantage of CAD capabilities. To understand why experienced users do not have this strategic knowledge, we explore three approaches. First, we review some of the training literature and demonstrate that this strategic knowledge is not defined or taught explicitly. Second, we suggest that in the absence of these strategies, users develop an approach that is a mixture of manual and CAD methods resulting in suboptimal strategies. Third, we attempt to understand why experienced users do not themselves realize and change their suboptimal strategies. This is done by analyzing the relationship between drawing strategies and the quality of drawing produced for manual drafting as well as for CAD. We conclude with an attempt to define explicitly some of the strategies that would improve the use of CAD systems and discuss the ramifications for training and design.

ANATOMY OF THE SUBOPTIMAL STRATEGY
We shall describe two examples where users demonstrate suboptimal strategies while performing CAD tasks.

Example 1
One of the users in our study (referred to as B1) modified a design file from a marked-up hard copy. His task was to draw fire protection enclosures around columns in a floor plan. The
fire protections are polygons patterned with dots and triangles symbolizing concrete.

To construct the fire protection enclosures for the first column, B1 had to draw two identically patterned, L-shaped polygons. As shown in Figure 1a, he first drew the top shape (1), and then mirror-copied the shape to create the bottom shape (2). He then poched (patterned) each of the shapes (3). A more efficient way would have been to detail the first shape by drawing and patterning it, and then mirror-copying the patterned shape to create the second shape. This strategy would have saved him the extra operations for patterning Shape-2.

In addition to the above strategy to complete the entire task, B1 also used a suboptimal method to complete the subtask of drawing the L-shaped polygon. To draw a closed shape that could be patterned, he used the method shown in Figure 1b which was very similar to a manual drafting technique. First he drew the top horizontal line (1), and then the left-most vertical line (2). Next he used the COPY PARALLEL command to make copies of the two lines drawn, (3), and used the MODIFY TO INTERSECTION command to cleanup the intersection of the two lines (4). Finally, he drew one endcap of the shape (5) and used the COPY PARALLEL command to make a copy of the inner elbow of the shape to create the lower endcap of the shape (6).

The above method to draw a shape with lines had two repercussions. First, as the automatic PATTERN command is designed to pattern only closed shapes, he had to pattern each shape by copying individual dots and triangles from a nearby concrete shape. Second, when he decided to mirror-copy the shape, he had to temporarily group the individual line segments together using the FENCE command before he could mirror-copy the shape. In the version of the CAD system used in our study, this procedure included several actions requiring the user to select individual pixels. This difficult perceptual/motor task was quite error-prone. Instead, if he had used the command PLACE ORTHOGONAL BLOCK to create the shape as a closed polygon, he could have used the automatic PATTERN command as well as the regular MIRROR COPY. These would have avoided the errorful steps of precise line drawing, manually patterning, and creating a fence to achieve the grouping.

It is pertinent to note that B1 had no difficulty in interacting with the commands he used. He rapidly executed commands like MIRROR COPY and even more complex commands like MODIFY TO INTERSECTION with only minor motor slips. However, what B1 did not exhibit was a strategy to decompose the task so these very commands are used in a way to avoid unnecessary steps.

Example 2
Lang et al. (1991) describes a similar suboptimal strategy used by an experienced CAD user. In their experiment, users were given the top and side view of a mechanical part drawn on paper. Their task was to construct three orthographic views and one isometric view of the part shown in Figure 2. According to the authors, the following four steps are an efficient way to complete the task:
1. Draw the four circles representing the arcs and holes.
2. Draw lines connecting the outer arcs as well as the lines constituting part of the keyhole.
3. Clean up the drawing by trimming lines that are not accurate or those used for construction.
4. Group appropriate elements in the two dimensional drawing and project them into the third dimension.

However, an experienced user in the experiment (referred to here as L1), executed the task differently from the efficient way described by the authors. L1 skipped step 3 and projected the two dimensional drawing before cleaning it up. Therefore, he had to clean up the drawing in two places. Similar to B1 in the previous example, L1 had little trouble using the commands. However, because the task was not decomposed into the proper subgoals, the resulting command sequence caused him to execute more steps than needed.

Lack of an Efficient CAD Strategy
The above examples show the effects of not using efficient CAD strategies. In example 1, the step of copying a group of elements only after all the details are completed is an important strategy to take full advantage of the Mirror Copy command. In example 2, the step of projecting a group of elements only after all the details are finished is once again an important strategy to take full advantage of the Project command. Both examples demonstrate a strategy that requires the explicit sequence of first detailing all the parts, then aggregating those parts, followed by manipulating the aggregation. This strategy has no clear advantage in manual drafting as there is no way to produce elements automatically. However, this strategy is particularly useful in CAD as it can assist in reducing the number of steps to complete certain tasks.

Example 1 also demonstrates a suboptimal strategy that occurs at the lower level of drawing a shape. The example shows the effects of not using an efficient CAD strategy of using shapes to draw closed polygons. This "closed shape" strategy, of course, has no meaning for manual drafting. There is only one way to draw the shape - with individual lines.

Although both the above users had many years of experience using CAD, they used suboptimal strategies to complete their tasks. To understand why these users did not demonstrate the use of efficient strategies, we investigated the nature of CAD knowledge and instruction provided in CAD manuals and books.

SEARCHING FOR EFFICIENT CAD STRATEGIES
To understand more clearly the levels of knowledge that were known and not known to users, we constructed a task decomposition of example 1 expressed as a GOMS model (Card et al., 1983). Figure 3a shows a partial task decomposition of B1 drawing the fire protection shapes. When compared to the efficient way to accomplish the task (Figure 3b), we can see that B1 executed the Mirror Copy too early, and therefore had to pattern both the shapes. Additionally, he drew the shape with single lines and patterned each shape manually by copying dots and triangles. Therefore he used 4 cursor inputs just to place dots in the first shape. Instead, as shown in Figure 3b, if he had used a closed shape combined with the automatic pattern command, he would have to select the shape only once to pattern it automatically. As this patterned shape can be mirror-copied, it would have saved him the extra step of patterning both shapes.

Therefore, while B1 was proficient in executing the commands in the lower part of the task decomposition, he did not demonstrate knowledge of an efficient strategy at the higher level. We therefore investigated whether the higher level strategic knowledge was contained in vendor provided manuals and other sources.

We found that the highly competitive CAD industry had spawned an explosion of features in CAD systems resulting in systems with up to 2000 commands and a corresponding increase of instruction material. Manuals provided by the market leaders AutoCAD and Intergraph, focus on providing users with volumes of information about the numerous features available. The MicroStation user’s guide, for example, begins with MicroStation Fundamentals which contains numerous exercises centered around commands like Save As and Draw Line. Although these descriptions are well presented, they are limited to the location of commands and the steps to use them. In addition to vendor supplied manuals, commercially available supplementary volumes reveal a similar pattern. They include only details of specific commands without any higher level strategies.

In a library search of CAD books for architects, we found only two books that went beyond the description of commands. One of the books (Obermeyer, 1987) states, "It might be necessary to discard some traditional drafting concepts as
you learn the sophistication of AutoCAD” (pg. v). The other book by Crosley (1988), describes the importance of “thinking CAD”. He states, “It’s possible to use computer-aided drawing without really taking advantage of its capabilities. Even some experienced CAD users have simply transferred all their manual-drawing habits over to the computer.” (pg. 6). Later he adds “Thus, the advantages of CAD are not free; they come at the expense of having to actually design the drawing” (pg. 11). While describing the COPY command he advises users to “never draw anything twice!” (pg. 41). While such advice goes a long way in stressing the importance of using commands like MODIFY TO INTERSECTION that were not present in manual drafting, it was not clear why the high level strategies like drawing a shape with single lines had such a remarkable resemblance to manual drafting. We therefore reviewed research in the area of knowledge acquisition and conceptual change to see if we could find an explanation.

MENTAL MODELS AND CONCEPTUAL CHANGE

Research on mental models describe a convincing picture of the stages that people go through while undergoing conceptual change in various domains. Clement (1983), for example, describes many adults who have a naive view of mechanics that has a striking resemblance to pre-Newtonian physics. The process of knowledge acquisition can be seen as the restructuring of these models that are based on naive or prior knowledge, to fit new information. Vosniou et al. (1992) describe this change in terms of synthetic models that have to go through weak restructuring to make them consistent with new information. Occasionally, however, when these synthetic models are faced with major anomalies, they have to undergo a radical restructuring before they can fit with the real world conceptual model.

The theory of mental models and conceptual change can be used to explain what appears to be occurring in the learning and use of CAD systems. While the experienced users were quite proficient in using complex CAD commands like MODIFY TO INTERSECTION that were not present in manual drafting, it was not clear why the high level strategies like drawing a shape with single lines had such a remarkable resemblance to manual drafting. We therefore reviewed research in the area of knowledge acquisition and conceptual change to see if we could find an explanation.
the CAD system as merely an electronic drafting tool requiring little change in the way drawing tasks are performed. Introductory descriptions often have statements like "CAD is an expansion of the way you draw" (Obermeyer, 1987, pg. 5), and go on by describing the use of the commands like Draw Line. The model of an electronic drafting tool is further reinforced by having concepts such as "drawings" and "layers" that are directly connected to the real world concepts of drawing sheets and overlay drafting (the use of overlapping tracing sheets). Following such introductions, the user is exposed to the details of using many different computer commands. The knowledge, as discussed earlier, is mainly about the location of these commands in deep hierarchical menus, and the procedure to execute them.

Immersed with tool knowledge but without explicit strategies to decompose tasks to make use of those commands, the users simply adjust their initial drafting model to incorporate the new knowledge of the commands. However, as described in the examples, this superficial adjustment causes problems. On the surface the use of Mirror Copy and Project appear to have been mastered as the users have no problem executing them. Because the underlying conceptual model is still an electronic drafting tool rather than a CAD system requiring different strategies, the overall use of these commands is sub-optimal.

Although the above explanation appears plausible, it cannot explain why CAD users do not discover the strategies over time and make a deeper conceptual change to their mental models. These users, performing complex drawing tasks for many years, have many opportunities for serendipitous discoveries of efficient strategies. Research in the stages of skill acquisition in many domains shows people who have successfully reached a stage of strategic learning. Strategic learning is described as "the improvement that comes about because people learn the optimal way to organize their problem solving for a particular domain" (Anderson, 1990, pg. 257). Why have the CAD users that we observed not reached this level of learning?

To understand why this change has not occurred, we contrasted the relationship between strategies and the quality of the product in manual as well as in CAD systems. We also explored the nature of the feedback loop for strategic knowledge in CAD systems.

**THE RELATIONSHIP BETWEEN TECHNIQUE AND QUALITY**

Manual drafting books have detailed descriptions of tools, techniques on how to use them, and simple rules to compose and perform a drawing task. Beakley et al., (1984, pg. 47), for example state that "When drawing, the lead should be pulled (not pushed) across the paper. To achieve this, tilt the lead holder in the direction of the hand movement when drawing a line. To reduce the frequency of sharpening standard size leads, slowly rotate the pencil as you draw a line". The book shows examples of 7 poorly drawn lines and their probable causes such as "pencil lifted too soon". In addition, techniques are provided to prevent lines from getting smudged and drawings getting dirty, for example, "... it is good practice always to begin work at the upper left corner of the sheet of drafting paper and to finish at the lower right corner of the sheet. Left-handed drafters may want to begin at the upper right corner of the sheet" (pg. 47). Still other techniques are provided to perform tasks requiring tool changes; "To avoid noticeably mismatched tangents, always draw circular segments first, then draw straight-line segments from the curved lines" (Ching, 1975, pg. 19).

These procedures are designed explicitly to achieve drawing accuracy and quality. In most cases, if these procedures are not followed, it is very hard to produce a quality drawing; a wrong strategy invariably leads to a visibly low quality drawing. Because there is such a strong causal relationship between technique and quality, and because the flaws are publicly visible, drafters tend to be highly motivated to improve their technique.

This strong causal relationship between technique and drawing quality is absent in CAD. The drawing produced by B1 in example 1, is accurate and clean. This is easy to achieve as it requires only basic CAD knowledge to place accurate lines that meet at intersections. Therefore, there is no visible indication that the drawing was produced by a suboptimal strategy. As the flaws in the technique are not publicly visible, the users neither notice their suboptimal techniques, nor have motivation to change them.

In cases when drawings are shared and manipulated within a group working on the same project, a poorly constructed CAD drawing can cause irritations and problems to other users. For example, a user might expect to move a shape by grabbing a side and realize it was constructed by single lines. In cases like this the drawing strategy becomes public. However, if all the users in a group share a common mental model of the CAD system, the suboptimal strategy can remain undetected. This is exactly the situation at the office where example 1 occurred.

The nature of the feedback could also explain why CAD users never reach the level of strategic learning. In the study by Lang et al. (1991), we find two examples of the value of feedback. When L1, in example 2, attempted to draw a line connecting two arcs, he drew only one arc before he started to draw the connecting line. As the line needed to be connected to the second arc, he did not have a precise location to end it. Having failed to complete the task of drawing the line, he abandoned the line to draw the second arc, after which he redrew the line connecting both the arcs. Therefore, the failure to complete the task provided him feedback to change his strategy. Furthermore, to test if he could perform the task more efficiently, L1 was asked to discuss his strategy with another user who had used the more efficient strategy, and then redo
the task. In his second attempt, L1 completed the task with the efficient strategy using many fewer steps. This demonstrated that remediation can help even an experienced user to realize and execute a better strategy.

However, while feedback through failure can occur for some tasks, and remediation might occur through peer contact, in most real-world situations they do not occur. In CAD, using a high level suboptimal strategy typically does not preclude the user from completing the task as there are many brute force ways to complete the task. Additionally, as observed in our site visit, while users frequently discuss design issues, they rarely discuss drawing strategies or look over each other’s shoulders during the drawing process. Therefore, as feedback through failure and remediation rarely occur, CAD users may never reach a level of strategic learning even after many years of experience.

AN APPROACH TO CHANGE THE CONCEPTUAL MODEL OF CAD

Understanding the structure and causes of a problem usually suggest solutions. First, we have seen that although strategic knowledge in manual drafting has been made explicit in books, there has been no such attempts for CAD. Second, while the products of CAD usage are public, the process of producing them is mostly private. We therefore have begun to explore ideas to address both these issues.

Making CAD Strategies Explicit

Whether the ultimate goal is to provide better training, feedback, or motivation, the first step is to make efficient CAD strategies explicit. An efficient CAD strategy is one that decomposes a task in a way that makes efficient use of the tools available. Additionally, these strategies should be sufficiently abstract so that, once learned, they can be used in a variety of contexts.

One way to identify efficient CAD strategies is to understand where CAD offers advantages over manual drafting. Figure 4 contrasts the task decomposition for manual drawing and CAD. The task is to draw three identical complex shapes consisting of lines and arcs. (We assume that the locations of these shapes have been determined through grids or construction lines). Due to the inaccuracy of the compass in manual drafting, the arc must be drawn first. However, to minimize tool changes, all the arcs must be drawn together (1). Next, the vertical lines can be drawn moving the set square from left to right to avoid smudging the lines (2). Finally, the horizontal lines are drawn for all the shapes (3). Therefore, the efficient task decomposition is determined by the nature of the manual tools.

In CAD, as shown in Figure 4b, the efficient way to decompose the same task is different. Because CAD provides aggregation and manipulation commands, it is better to first draw all the lines of the shape (1 & 2), group them (3), and then make two copies (4). This strategy is what we call the Detail-Aggregate-Manipulate (DAM) strategy. The suboptimal strategies in example 1 and 2 described earlier, occurred because the detailing stage of the DAM strategy was not completed before starting the aggregation stage. B1 mirror-copied the shape before patternning it, and L1 projected the two dimen-

![Figure 4. Comparing manual and CAD strategies](image)

A. Manual Drafting Strategy


B. CAD Strategy


AGGREGATION (AGG, CELL) and manipulation commands (MOVE, COPY, ROTATE) and modify them (SCALE, PARTIAL DELETE, ADD VERTEX) to create a similar but not identical result. This strategy can therefore be called Locate-Aggregate-Manipulate-

The contrast between the manual and CAD way to decompose the same task, as shown in Figure 4, suggests an important difference in the nature of assistance provide by the two media. While the manual drafting medium assists in the creation of geometry (lines, arcs etc.), it does not assist in exploiting the structure of a drawing (repetition, symmetry, projection, configuration). In contrast, the CAD medium, while supporting geometry creation, also provides assistance to exploit the structure of a drawing. However, this assistance can be beneficial only if a strategy such as DAM is used. The DAM strategy appears to be powerful as it has numerous applications, some of which are shown in Figure 5. Given the description of this strategy, one can begin to imagine other forms of suboptimal behavior. A user, for example, might detail the shape, ignore the aggregation stage, and proceed to copy the shape element by element.

CAD systems also provide powerful modification commands such as ADD VERTEX and PARTIAL DELETE. Such commands in combination with manipulation commands allow a user to exploit the occurrence of compositions that are similar in a drawing, a capability that is not supported in manual drafting. The CAD system can therefore assist the user to access and locate any part of a drawing (PAN, ZOOM, REFERENCE FILES), aggregate elements that are similar to the task at hand (FENCE, GRAPHIC GROUP, CELLS), manipulate the aggregation (MOVE, COPY, ROTATE) and modify them (SCALE, PARTIAL DELETE, ADD VERTEX) to create a similar but not identical result. This strategy can therefore be called Locate-Aggregate-Manipulate-
Modify (LAMM) and can be applied in many different contexts.

We suspect that there are efficient strategies at every level of CAD that need to be made explicit, from organizing a project to accurate cursor input. While strategies such as DAM and LAMM might appear obvious, the value of stating them explicitly cannot be ignored as even experienced users do not seem to be using them. However, it is yet an empirical question as to whether these strategies can be conveyed and learned by users through well-designed instructional aids. It appears that if these strategies and their applications are taught early during training, users can be encouraged to decompose drawings in terms of concepts like repetition and similarity. Such concepts are not new to designers who use them constantly in their designs. However, for reasons we have offered, many users may not be using the CAD medium to exploit the very concepts that they use in design. In addition, if CAD users are introduced early on how to decompose a drawing task ("thinking CAD"), they might be motivated to search for and learn the commands that allow for actions like aggregation and manipulation. In fact it might be possible to reorganize the commands in an interface based on task goals such as symmetry and similarity. This might encourage users to recognize and exploit the structure in a drawing.

**Providing Feedback**

Another approach that we are exploring is to provide computer based feedback to users when they use suboptimal strategies. We have prototyped a system called Active Assistant (Bhavani et al., in press; Bhavani et al., 1994) that monitors various events while the system is being used, and provides unobtrusive assistance when appropriate. So, for example, the system might detect that a closed shape has been drawn with single enclosing elements and trigger the assistance. The assistance might replay the steps that a user executed to create the shape and present advantages of doing it another way. It is hoped that because the feedback is immediate and situated, the user will learn to look critically at their drawing process and motivate them to use better strategies. However, it remains to be seen if such a system would actually produce a change in the behavior of a user. Encouraging peer interaction and review might be equally powerful mechanisms.

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**Figure 5. Applications of the DAM strategy. Each row represents a type of structure found in drawings, with a single instance of a command sequence to exploit that structure.**

<table>
<thead>
<tr>
<th>Structure in Drawing</th>
<th>Strategy</th>
<th>Detail</th>
<th>Aggregate</th>
<th>Manipulate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replication</td>
<td>1. Draw All Elements 2. Fence Elements 3. Copy Fence</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Projection</td>
<td>1. Draw All Elements 2. Boolean Shapes 3. Project Shape</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Configuration</td>
<td>1. Draw All Elements 2. Create Cell 3. Construct Array</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
CONCLUSION
We have attempted to explain why experienced CAD users not only use suboptimal strategies to complete drawing tasks, but also continue to do so even after many years of CAD usage. This, we believe, has three causes. First, the strategic knowledge to use a CAD system efficiently has never been made explicit, and therefore never taught. Second, as there are few mechanisms that provide feedback about suboptimal usage, users frequently may not be aware of their suboptimal usage. Third, as users can most often produce clean accurate drawings however suboptimal their strategies, there is little motivation to look critically at their drawing process.

In an attempt to reverse this situation, we showed two examples of how CAD strategies can be abstracted and explicitly stated. Such strategies could be used to design various forms of instruction as well as to redesign the interface. We also briefly described an approach to provide unobtrusive feedback to users if they performed tasks using suboptimal strategies.

One of the most common and favorite explanations for the low productivity in CAD systems is that the “D” in CAD does not stand for Design. Many claim that architects design, not just draw and therefore CAD systems as they stand today should be abandoned and approached differently. We believe this line of argument misses the point. Whatever the original acronym meant, CAD systems were designed to assist in drawing and not in design. While new paradigms for design assistance have to emerge and prove themselves, there are lessons to be learned from the CAD productivity problem.

The CAD productivity problem, as we have demonstrated, has to do with deeper mechanisms that can plague the proper use of any new technology or medium. If the CAD productivity phenomena is ignored or explained away by the nature of what CAD systems do, then we are doomed to repeat their mistakes. If, on the other hand, we understand that a new technology often requires reformulating old tasks, then we can spend more time in making that knowledge explicit and minimally disruptive. Bowen (1989) studying the productivity puzzle states: “The large payoffs come not from increasing the efficiency with which people perform their old jobs, but from changing the way work is done”. However, it appears, that the knowledge to make this change is often not as obvious to users as we might assume and while serendipitous discoveries by users are possible, it is not something we should depend upon.

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What does it mean to design a mind tool?
How the Goal of Intelligence Augmentation
Will Influence the Design of Advanced Virtual Reality Interfaces

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DO DESIGNERS OF ADVANCED INTERFACES BELIEVE THEY ARE CREATING MIND TOOLS?
Can any computer truly enhance the functioning of the human mind? Can steel and silicon be so harmonized with the chemistry of the brain, that one amplifies the other? If human intelligence is partially shaped by the environment, can a highly enriched virtual environment augment human intelligence? At its essence this is almost the same as asking: Can we design a mind tool? If the advanced computer interfaces we design do not somehow assist human intelligence, then they are not cognitive technologies or mind tools. The notion that computers could assist human intelligence or embody human intelligence has been one of the dominant ideas in computer design in the second half of the twentieth century.

The design of computer interfaces is frequently accompanied by claims that they will assist mental labor or somehow augment the functions of the mind. For example, it is often claimed that computers in general and advanced interfaces in particular help the productivity of mental work. A specific program is said to make you think faster, be more creative, consider more options, learn faster; etc. The belief that computer interfaces assist human intelligence is at the very heart of most designers’ proposals for the use of advanced computer interfaces in training, education, corporate decision making, the arts, medicine, and numerous other fields. I will argue that the goal of intelligence augmentation lies at the very heart of the design of advanced interfaces. Furthermore, the claims of intelligence augmentation are present more often at the frontiers of human-computer interactions, for example immersive virtual reality. I believe that this claim and its assumptions will permeate the goals and assumptions of the human-computer interface design process in the future. There are three reasons for believing this issue will be central:

(1) cognitive claims are implicit in most design theory and rhetoric,
(2) the emergence of the model of the brain that reveals significant plasticity in response to environmental variables, including the extended use of artifacts,
(3) and an increasing focus on the design of advanced interfaces in facilitating various forms of human thought.

If these assertions are true, then it is important that we attempt to better understand and dissect the cognitive assumptions behind design processes that make claims about the design of “mind tools” and the goal of “intelligence augmentation.”

WHAT DOES IT MEAN TO SAY THAT WE ARE DESIGNING “MIND TOOLS”?
The example of immersive virtual reality design.
But what does it mean to say that computers are “mind tools”? How and in what way do they or might they assist human intelligence. If they really assist mental labor, what are the implications of the mind freed from certain mental task? Does a mind linked to a mental prosthesis work differently? Better? Or is it just released from some mental burden?

Nowhere is a belief in the intelligence augmenting power of computers more pervasive than at the frontiers of interface design, the place where computer, body, and mind meet. Here one finds various forms of virtual reality interface design. The notion of a computer linked to the body and assisting the mind is central to the design of advanced virtual environment systems. From the very beginning VR engineers and programmers have conceived of the medium as a cognitive technology, a technology created to facilitate cognitive operations (Brooks, 1977, 1988; Furness, 1988, 1989; Heilig, 1955/1992; Krueger, 1991, p. xvii; Lanier & Biocca, 1992; Rheingold, 1991; Sutherland, 1968). For a large segment of computer
graphic engineers and programmers, virtual reality technology marks a significant milestone in the development of computer interfaces (Foley, Van Dam, Feiner, Hughes, 1994). Fulfilling a long term goal in the history of media (Biocca, Kim, & Levy, 1995), many feel that VR promises to finally create compelling illusions for the senses of vision, hearing, touch, and smell. In the words of a respected VR designer who has helped pioneer systems at NASA and the University of North Carolina, “The electronic expansion of human perception has, as its manifest destiny, to cover the entire human sensorium” (Robinett, 1991, p. 19).

Like a bright light just out of reach of their data gloves, VR designers stretch their arms to grasp an enticing vision, the image of virtual reality technology as Sutherland’s “ultimate display” (Sutherland, 1965), a metamedium that can augment human intelligence. Engineers and programmers attempt a masterful orchestration of electricity, LCDs, hydraulic cylinders, and artificial fibers. With these, they hope to so dilate the human senses that waves of information can pour through this high bandwidth channel into the brain. In full union with the user, virtual reality might emerge to be a universal “tool for thought.” In this vision virtual reality would extend the perceptual and cognitive abilities of the user.

The claim that virtual reality may augment human intelligence is based on the increasingly compelling sensory fidelity of virtual worlds. The computer graphics and kinematics capture more and more of the physical and sensory characteristics of natural environments. Immersive VR simulations perfect the way the virtual environments respond to user actions: the link of physical movement to sensory feedback increasingly simulates human action in a natural environment (Biocca & Delaney, 1995). The designers’ confidence in the cognitive potency of these environments results in part from the very experience of the medium, the deep gut level reaction that designers and users feel when immersed in high-end VR systems. This experience suggests to some that VR has crossed a threshold never reached by older media. More than any other medium, virtual reality gives the user a strong sense of “being there” inside the virtual world. The senses are immersed in an illusion. The mind is swathed in a cocoon of its own creations. The word, “presence,” (Sheridan, 1992; Steuer, 1995) has come to mean the perceptual and cognitive sensation of being physically present in a compelling virtual world.

Let us consider the design agenda that motivates advanced interface designers’ claims regarding cognitive technology. What do these claims portend for the future of design? I will focus on the claims made regarding fully immersive virtual reality, arguably the most advanced computer interface. I will try to dissect the goal of intelligence augmentation that beats in the heart of VR design. I will consider the following question: What are the claims implicit in the idea of intelligence augmentation through the design and use of advanced computer interfaces such as virtual reality?

What are they? How are they conceptualized? Are they valid? How do such claims influence the design process?

ORIGINS OF THE IDEA OF INTELLIGENCE AUGMENTATION IN INTERFACE DESIGN

Sir Francis Bacon saw in technology a “relief from man’s burden.” There is a difference between the way technologies of artificial intelligence (AI) and intelligence augmentation (IA) approach this problem (Biocca, 1996). Technologies of artificial intelligence try to produce a silicon slave, an agent, to perform mental labor. Technologies of intelligence augmentation try to produce a mind tool to enhance the same labor. This notion of relief from labor has often been accompanied by a related thought, the idea that relief from drudgery elevates the human mind for higher things. In the early days of computer design when VR, hypertext, and the World Wide Web were but phantasm floating above a hot noisy box of vacuum tubes, Vannevar Bush wrote an early form of the proposal for computer-based augmentation of human intelligence in his classic article, “As we may think” (Bush, 1945). He looked at the emerging mind tool and articulated four key goals:

(a) relief from the “repetitive processes of thought” (p. 4);
(b) improved methods for finding, organizing and transmitting information;
(c) “more direct” means for “absorbing materials through the senses” (p. 8);
(d) improved means of “manipulating ideas” (p. 4).

Bush’s name is often invoked in discussions of the vision of the Internet. But Bush’s dream of a computer tool he called “Memex” was to be more than a hypertext engine. It was also designed to be a VR-like device for augmenting intelligence by channeling electrical information through the senses:

In the outside world, all forms of intelligence, whether sound or sight, have been reduced to the form of varying currents in an electric circuit in order that they may be transmitted. Inside the human frame exactly the same sort of process occurs. Must we always transform to mechanical movements in order to proceed from one electrical phenomenon to another? (Bush, 1945, p. 8).

In the work of later designers, Bush’s ideas evolved. The machine would not only liberate the mind for higher things; it would augment it. Like a vacuum tube it might amplify the neuronal currents coursing through the brain. With the invention of the mouse — a simple 2D input device — the body entered cyberspace (Bardini, in press). In the work of its inventor, Douglas Engelbart, we see the most explicit expression of the goal that VR has inherited his project for the “augmentation of the human intellect.” In the words of Englebart in a government report:

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By “augmenting the human intellect” we mean increasing the capability of a man to approach a complex problem situation, to gain comprehension to suit his particular needs, and to derive solutions to problems. Increased capability in this respect is taken to mean a mixture of the following: more-rapid comprehension, better comprehension, the possibility of gaining a useful degree of comprehension in a situation that previously was too complex, speedier solutions to problems that before seemed insoluble.

Augmenting man’s intellect...can include... extensions of means developed . to help man apply his native sensory, mental, and motor capabilities — we consider the whole system of the human being and his augmentation means as proper fields of search for practical capabilities. (Englebart, 1962, p. 1-2)

VR is now a major site where the “search for practical capabilities” attempts to apply our “native sensory, mental, and motor capabilities.” Englebart’s project takes place at the cusp of the 1960’s, a decade known for the pursuit of human and social transformation including the use of chemical technologies for “mind amplification.” These cultural themes of human transformation and perfectibility achieved further expression in the human potential movement of the 1970s and 1980s. By the 1990s human potential enthusiasts like Michael Murphy, co-founder of the Esalen Institute, were cataloging massive lists that purported to show “Evidence of Human Transformative Capacity” (Murphy, 1992). But this movement dwelled on the older technologies of eastern ascetic, religious, and medical practice. This cultural thread — very much alive in places like Silicon Valley — would come to rejoin virtual reality technology in the early days of its popularization. The mixture of these themes was welcomed and echoed in such cultural outposts as the magazines Mondo 2000, Wired, The Well, and Cyberpunk culture.

It is on the borders of this frontier, that VR research rides out toward the forward edges in pursuit of intelligence augmentation. But earlier notions that the machine would free the mind for “higher” things was sometimes born of a disdain for physical labor. A Cartesian distrust of the body and the evidence of the senses tinged this sentiment. But VR’s research program embraces the body and the senses with Gibsonian notions (Gibson, 1979) of the integration of the moving body, the senses, and the mind. Its most ardent enthusiasts promise to augment the mind by fully immersing the body into cyberspace. VR promises to take the evolutionary time scale both backwards and forwards by immersing mind and body into a vivid 3D world, from the open savanna to fields of data space. VR suggests we take the external storage system that was born when the first human symbol was stored in sand or clay and immerse each sensory channel into vivid semiotic fields of human communication activity. Reflecting the interaction of technology and the body, Jude Milhon, an editor of Mondo 2000 proclaimed, “Our bodies are the last frontier” (Wolf, 1991). Standing on the edge of that frontier, we ask: Will the sensory immersion afforded by VR — this multisensory feedback loop between social mind and its creations — amplify, augment, and adapt the human intellect? Can such a vision guide a research program? How do VR designers conceptualize this outcome they pursue?

**HOW IS INTELLIGENCE AUGMENTATION CONCEPTUALIZED?**

**Two phases: Amplification and Adaptation**

Ideas about a VR-like machine that can augment intelligence have been advanced primarily by computer scientists and rarely by psychologists (e.g., Brooks, 1977; Bush, 1945; Licklider & Taylor, 1968; Heilig, 1955/1992; Krueger, 1991; Sutherland, 1968). The conceptualization of intelligence augmentation has sometimes been wanting - the technology was claimed to somehow assist thinking or augment human performance. How it will assist thinking is not always specified.

Most technologies, but especially communication media, interact with cognition in one of two ways. Figure 1 illustrates these two phases in the interaction of mind, medium, and environment:

(a) *amplification*, tools that amplify the mind;
(b) *adaptation*, mediated environments that alter the mind.

This distinction not only captures two phases in the interaction of humans with technology, it also suggests two types of theoretical claims. When theorists say that a medium like virtual reality *amplifies* cognition, it is implied that those operations are not fundamentally altered. The mind remains as it was before contact with the technology. When theorists argue that a medium *alters* cognition then a stronger claim is made; the mind has adapted in some way to the medium.

Many theorists would argue that cognitive amplification tends to lead to cognitive adaptation. For example, this is what McLuhan meant by the “Narcissus effect” of media: we embrace some aspect of ourselves (our objectified mind) and become fixated and defined by this one facet of ourselves. A set of cognitive operations, a part of us, is selected, favored, and augmented. We are changed through the selective enhancement of cognitive skills.
Amplification
Claims that media amplify cognition group into three general types: sensorimotor amplification, simulation of cognitive operations, and objectification of semantic structures.

Sensorimotor Extension
McLuhan (1964, 1966) popularized the notion that media “extend the senses.” McLuhan was unknowingly continuing a long tradition in engineering philosophy that saw technology as organ extension (Mitcham, 1994). This position is now widely accepted. Media are seen as prostheses - once attached they extend the body or mind.

In what way might this augment intelligence? Human intelligence is provided with more sensory data and experience when the senses are extended over space (e.g., telephone, remote sensing), overtime (e.g., photography), and beyond the bounds of normal sensation (e.g., infrared goggles). Before the arrival of advanced VR telepresence systems, media extended only the visual and aural senses, for example, the way a remote controlled video camera extends our vision and hearing into another room.

VR expands the possibility of sensorimotor extension. More senses are addressed with illusions of greater fidelity. But VR also integrates the actions of the body and the senses in a more “natural” way when it extends them. Many older technologies extend motor capabilities but provide poor feedback. For example, a back hoe extends the scooping action of the arm and hand, but provides little more than visual feedback. VR telepresence systems may improve both human performance and amplify human intelligence by closing gaps in the feedback loop between action and sensation. The user can explore distant real environments or purely virtual environments with more of the body.

Simulation of Cognitive Operations
To the degree that many technologies are extensions of the body, they simulate physical and mental processes. Mental processes require mental labor. If the labor is transferred to some electromechanical entity, then more brain capacity may be available for pattern perception, decision making, and creativity. This proposition has been the driving force behind the design of the computer since at least the days of Babbage—if mathematical processes can be simulated by gears, tubes, or silicon, these mental operations could be amplified in speed and complexity. In this way human intelligence might be freed and amplified.

At the moment, designers clearly do not yet know how to best represent and simulate mental operations. It is one thing to conceptualize mental models (e.g., Johnson-Laird, 1984), it is another to build a tool that amplifies them. It is not yet clear how best to use the unique capabilities of VR technology to teach, assist, or augment cognitive skills. It is not clear how much of the existing research about media and development of cognitive skills applies (e.g., Salomon, 1979; Wetzel, Radtke, & Stern, 1994). At the moment designers are merely importing techniques they have been used to instruct individuals using pictures, film, and animation. The unique representational capabilities — the “language” of the medium — are only beginning to be explored (e.g., Meyer, 1995).

Storage: Objectification of Semantic Structures
Intelligence can be augmented by the objectification of a mental structure in some material form. The use of external memory storage systems is an evolutionary development that helped the emergence of the human mind (Donald, 1993). The objectification of semantic structures is the very essence of all semiotic systems (Eco, 1976): media and the codes they use allow users to record, store, exchange, and manipulate.
ideas. Various forms of computer technology are replacing older interfaces and storage media like the notepad, the drafting board, and the physical model. The objectification of semantic structures in a code or message reduces attention and memory load while augmenting the performance of creative and decision-making processes.

Most computer systems allow users to easily manipulate thought objects by manipulating symbolic objects. The most common is the objectification of a semantic network in some medium: outlines, diagrams, lists, etc. During decision making, concepts can be scanned. They can be made contiguous or linked in some way: hierarchical modeling, causal modeling, etc. There is evidence that the spatialization of thought, the objectification of symbolic tokens in a spatial structure, appears to augment human intellectual performance. The work on data visualization is based on the notion that human performance can be enhanced if abstract information is spatialized. It is proposed that human intelligence can detect patterns in abstract relations by using the ability of the senses to detect patterns (invariances) in the visual field. VR designs promise to extend this to all of the senses.

Adaptation

Intelligence amplification involves the augmentation of human intellect without any significant change in intelligence, i.e., changes in cognitive processes or structures. A crane or back hoe may amplify the power of the human arm, but it does not alter the arm in any way. The concept of adaptation suggests that the amplification of human intelligence through a medium may alter cognitive processes and structures. The mind adapts in function or structure to the medium.

When humans and technology come in contact, we can observe both short and long term human adaptation. Broadly speaking, adaptations following the use of a technology can be psychological, behavioral, and physiological. Look down towards the floor and take a look at a simple technology like the shoe. Mentally compare your foot to that of a shoeless Kalahari Desert Bushman. OK. Think about the shape of that foot. Any urban dweller can observe that long term use of the shoe may create a structural adaptation in the shape of the human foot (e.g., the toes curl inward and push against each other) and texture of the sole (e.g. a less callused and softer sole). This is a simple, easily observable physiological adaptation of the morphology of the body brought on by the extended use of a simple technology we take for granted.

Now let’s consider the idea of cognitive adaptation to VR systems. I am not talking about biological or evolutionary adaptations. These are epigenetic, not philogenetic changes. Adaptation of cognitive processes might emerge from either long term or short-term use of a medium. Because VR is a new technology, most of our experience is with short-term adaptations. But the issue of adaptation is already a central problem in VR design. For example, some users experience simulation sickness (Biocca, 1992) when using VR systems. Simulation sickness appears to be related to motion sickness. To some degree, simulation sickness is caused by the inability of the brain to reconcile and adapt to discordant spatial cues impinging on the senses immersed in the VR systems (i.e., vision) and cues from the physical environment (e.g., proprioception). The body’s response to this intersensory conflict is simulation sickness.

VR systems are imperfect. Designers assume that the user’s perceptual and proprioceptive systems will adapt to the medium. A study of adaptation to an augmented reality system showed that the perceptual-motor system does rapidly adapt to the sensory alterations of a VR system (Biocca & Rolland, in press). Subjects’ eye-hand coordination was significantly adapted as a result of a virtual displacement in felt eye position. Once users removed the VR equipment, their hand eye coordination remained adapted to the VR environment. They made significant pointing and reaching errors. They had to learn to readapt to the natural environment. Note that none of this evidence of adaptation shows any augmentation in human cognitive performance. These adaptations or failures to adapt are all decrements in human performance. This is not to say that VR will not lead to adaptations that augment cognitive processes and structures. For example, long term use of VR may augment spatial cognition. But there is little evidence of this yet, though we can observe improvements in human performance. The interesting questions as to whether long term use of the medium can augment human performance through adaptation remains unanswered.

KEY DESIGN HYPOTHESES LINKED TO THE GOAL OF INTELLIGENCE AUGMENTATION

A set of design postulates and hypotheses that are psychological in nature motivate the design of VR. A VR designer at Autodesk and the University of Washington’s Human-Interface Technology Lab (HITL), William Bricken, captured the essence of VR design when he pithily pronounced: “Psychology is the physics of virtual reality” (quoted in Woolley, 1992, p. 21). Virtual worlds are constructs of the senses. The psychological reality of VR is what matters in the final analysis. Therefore, many design principles are based on implicit or explicit psychological postulates and hypotheses. Many of these pertain to the design goal of intelligence augmentation. I would like to briefly discuss the key ones that appear to drive the design of VR. They are often advanced as postulates, but I will treat them as hypotheses. Each suggests references to a number of psychological theories. I will not refer to these here, but rather present each hypothesis as VR designers use it.

The Bandwidth Hypothesis:

Advanced media (e.g., VR) can increase the volume of information absorbed by a human being.

If media are information highways, then designers see VR as a potential superhighway to the mind. The goal is the feeling of presence (Sheridan, 1992). The senses are the delivery
vehicle. VR designers try to deliver enough veridical information to the senses, so that a coherent, stable, and compelling reality emerges inside the mind of the user. As Warren Robinett, designer of an early NASA system and the University of North Carolina, "I want to use computers to expand human perception" (Rheingold, 1991, p. 25). On the engineering side this manifests itself as four design goals:

1. increase the number of sensory channels addressed by VR;
2. increase the sensory fidelity and vividness within each sensory channel;
3. increase the number of motor and physiological input channels;
4. link and coordinate the motor outflows (i.e., walking, head turning) to sensory inflows (i.e., visual flow) so that they match or even exceed those found in the natural environment.

In simulator systems (e.g., driving and flight simulators) the bandwidth hypothesis is straightforward. The goal is "fidelity." The design attempts to precisely match all the relevant sensory characteristics of the real world, task environment, "(1) the physical characteristics, for example, visual spatial, kinesthetic, etc.; and (2) the functional characteristics, for example, the informational, and stimulus and response options of the training situation" (Hays & Singer, 1989, p. 3). The user learns a set of perceptual discrimination and motor tasks by doing them. In an imperfect system, when absolute fidelity is not possible, the problem becomes determining what are the most "relevant," task-related cues.

**more sensory channels = more knowledge**

But the argument for increased sensory bandwidth goes beyond the goal of replicating natural environments. One also finds an implicit or explicit argument that suggests the greater the number of sensory channels and the greater the sensory information, the better the learning. Various versions of this proposition have proponents in the VR design community. For example, master VR designer Fred Brooks asserts, "we can build yet more powerful tools by using more senses" (Brooks, 1977). Even as early as 1965, Sutherland argued that the computer "should serve as many senses as possible" (1965, p. 507).

The bandwidth hypothesis is a seductive idea. It has accompanied many proposals for augmenting human intelligence through computer interfaces. For example, the influential work of master designer Alan Kay contained a version of the bandwidth argument when he outlined a design for an all purpose learning machine he called the "dynabook ... a dynamic media for creative thought" (Kay & Goldberg, 1977). Researchers have tended to emphasize the portability of the dynabook, but more important was the notion that the dynabook was to be a "metamedium' (that) is active." In its interactivity the metamedium was to "trace your senses...and could both take in and give out information in quantities approaching that of the human sensory systems." (Kay & Goldberg, 1977, p. 32). Intelligence augmentation was one of the goals of this device. Kay hoped to help the user "materialize thought and, through feedback, to augment the actual paths the thinking follows" (Kay & Goldberg, 1977, p. 31). Kay & Goldberg summarized a design prejudice that is now widely shared by the VR community, "If the medium is the message," then the message of low-bandwidth is 'blah'" (1977, p. 33).

**The Sensory Transportation Hypothesis:**

*VR can better transport the senses across space, time, or scale.*

Media historian Harold Innis (1951) was among the first to focus on the role of communication media in the manipulation of space and time. VR technology advances this function of communication media. But with VR, the manipulation, construction, and reconstruction of space is central to the use of the medium. It is clearly central in the construction of virtual space, that 3D illusion that beguiles the sensorimotor channels of the user.

But manipulation of space has another important role in VR technology. Some dimensions of the technology emerged from the research program in telerobotics. The central goal of the program of telerobotics and telepresence is not the construction of cyberspace, but the collapse of physical space. The collapse of space is built on the electronic transportation of the senses across space. In his greetings at the first IEEE Virtual Reality Annual International Symposium (VRAIS), Tom Furness, Air Force VR pioneer and a leading VR engineering researcher, proclaimed that "advanced interfaces will provide an incredible new mobility for the human race. We are building transportation systems for the senses ... the remarkable promise that we can be in another place or space without moving our bodies into that space" (1993, p. i).

At the distant frontiers of VR's transportation mission lies an agency whose sole mission is the collapse of space. NASA is developing virtual reality as a means of transmitting the experience of being telepresent on distant planets (McGreevy, 1993). At the other end of the spatial scale are VR systems squeezing the human senses down into the space that surrounds atoms. Work at the University of North Carolina (Robinett, 1993) ties the virtual reality interface to the end of a scanning-tunneling microscope. Atoms become mounds on what looks like a beach of pink sand. Atoms can be "touched" and even moved; the pink sand reshapes itself and new mounds appear. Both of these examples are different forms of one way to augment human intelligence: the extension of sensorimotor systems.
The Expanded “Cone of Experience” Hypothesis: Users will simulate and absorb a wider range of experience.

There is a materialist streak in the VR community, learning is seen as the direct outcome of experience. It is reasoned that more experience leads to more learning. But the argument is slightly more complex. Harking back to Dewey and Gibson (1979), there is an implicit proposition that 3D sensory, and interactive experience is at the core of learning invariants and patterns in the environment. The promise of VR brings out another function of media: the simulation and modeling of the world of experience. This function of media is as old as the theater and role-playing.

Media, such as VR, can be characterized as expanding the “cone of experience.” The human can vicariously experience a wide range of situations. The range of experiences and the diversity of models of problem solving and action have been augmented by communication using existing media. VR promises to expand the capability of media by making the expanded cone of experience a little less vicarious. Unlike books, the user need not use as much imagination to fill in the mental simulation. VR designers try to directly engage the automatic, perceptual processes to deliver an intense simulation of an experience. This is the essence of the goal of delivering experience that gives users “a sense of presence.”

VR proselytizer and artist, Jaron Lanier, was fond of suggesting that the goal of VR is the construction of a personal “reality engine,” an all purpose simulation device (Lanier & Biocca, 1992). This is far beyond what the technology can do, but developments far short of this goal may have effects on the amplification of human intelligence.

The property of VR, alluded to by Lanier and embodied in this hypothesis, involves two aspects of intelligence augmentation: the attempt to simulate cognitive operations and the expanded experience of objectified semantic structures. VR experience is never pure, unmediated experience. It is objectified, culturally filtered experience. VR like all media, exposes the user to predigested cultural understandings. As Jaron Lanier has observed, “Information is alienated experience” (Rheingold, 1991).

The Sensification of Information Hypothesis: Relationships in abstract information are better perceived and learned when mapped to sensory/spatial/experiential forms.

Sensification is a generalization of the concept behind the terms “visualization” and “sonification.” It means the creation of representations that use the information processing properties of the sensory channels to represent scientific data and other abstract relationships. Work arguing for the value of sensification for intelligence augmentation often has a neo-Gibsonian (1979) cast. It is argued that over thousands of years of evolution, the mind and the body have evolved to move, think, and act in a 3D environment.

Because of the limitations in our symbolic systems and representational technologies, our means of communication have not been able — until now — to fully harness the rich multisensory, spatial, and kinematic components of human thought and problem solving. VR, more than any other medium, comes close to providing an environment that has all the sensory characteristics of the physical world in which our brain has evolved, while retaining the responsiveness and flexibility of abstract semiotic systems like language and mathematics. In some VR systems scientists sail through 3D scatter plots, chemists pick up 3D models of molecules with their hands to think up new pharmaceuticals, and stock market patterns are perceived through a cave-like corridor of undulating curves and changing sounds.

The goal is to take the pattern detection capabilities of the senses, the spatial modeling capabilities of the eyes, ears, and muscles, to perceive, model, and manipulate ideas. The work on scientific visualization suggests the possibility for increased ability to detect patterns in data, faster problem solving and more creative ideas. These are some of the cognitive outcomes Engelbart (1962) sought from his project to augment human intelligence. In essence, it is argued that advanced sensory displays can augment human intelligence by involving the senses more directly in the perception and manipulation of iconic entities.

Amplification of Interpersonal Communication Hypothesis: Humans will be able to express and receive a broader range of human emotion, intention, and ideation.

All the propositions so far have emphasized the augmentation of what Howard Gardner (Gardner, 1977) would call logico-mathematical and spatial intelligence. Until recently, most VR systems have involved a single operator moving in a socially barren environment. Those social VR environments that existed for the most part have been designed for the military. The primary interpersonal interaction is search and destroy — more the augmentation of interpersonal annihilation than the augmentation of interpersonal communication.

As VR matures and multiple users can be represented in VR environments, more researchers are considering the use of VR to amplify interpersonal communication (e.g., Biocca & Levy, 1995; Palmer, 1995). Part of the early mission of intelligence augmentation through computer design was the creation of a “more effective” means of interpersonal communication (Licklider & Taylor, 1968). Most existing media like the telephone and email transmit only reduced personal presence.
The primary goal with most design in this area has been telepresence, the attempt to reproduce most of the cues found in interpersonal communication (e.g., Morishima, S. & Harashima, H., 1993). This goal, if achieved, would do nothing more that reproduce any common face-to-face interaction. This is no small achievement. It involves the transportation of the sensorimotor channels. But it is hard to see how simply recreating an everyday interpersonal interaction could augment human intelligence.

Some writers have speculated about the design of hyperpersonal or hypersocial VR environments. In these environments VR tools would amplify interpersonal interaction cues such as facial expression, body language, and mood cues. For example, Jaron Lanier (Lanier & Biocca, 1992) has speculated about how VR environments could be designed to alter body morphology to signal mood. Biocca and Levy (1995) have discussed expanding the sensory spectra of users by mapping physiological responses such as brain rates, heart rate and blood pressure to properties of the environment such as room color to signal mood and cognitive states. There have been few experiments in this area. It is not at all clear in what direction such tools would influence interpersonal communication or the augmentation of human intelligence. This design goal is an expression of an ancient desire to have communication tools so expressive that one can “enter another’s mind.” It is unclear whether or how much VR can bring us closer to this desire to inhabit another consciousness.

INTELLIGENCE AUGMENTATION: CAN A VISION BECOME A “SENSIBLE” RESEARCH AND DESIGN PROGRAM?

The overall goal of augmenting the human intellect is a highly motivating vision of the possible utility of the cognitive technology. It has also become a research program. The ideas listed above motivate design and research work in the area of VR. Researchers in VR labs around the world explicitly or implicitly subscribe to one or more of them.

Each hypothesis (design postulate) mentioned above is as much vision as it is scientific hypothesis. In some ways the very nature of these “hypotheses” indicates a difference between the design sciences and the natural sciences. The “hypotheses” are not just about the “discovery” of scientific laws. They are teleological in spirit (Biocca, Kim, & Levy, 1995). They reflect human goals, the desire to exercise human will in the construction of an artifact — the very creation of virtual and cognitive reality. Are these goals attainable? I leave the full answer to this question to another paper or to another 50 years of research. We might ask a more modest question here: Are these hypotheses sensible? Can they be founded on any valid evaluation of the technology or of the plasticity and abilities of the human mind? After all, we hardly know what “intelligence” is, how can we hope to “augment” it? Each “hypothesis” will certainly require more profound theoretical elaboration as both research and design move forward.

Can increased sensory fidelity improve human performance?

As an example, let’s consider one set of ideas that would require more theoretical elaboration as they are transformed from visionary proclamation to a concrete theory of human-computer interaction. A number of the hypotheses share a common assumption that simply increasing the sensory fidelity or vividness of information will improve human performance. To many, this seems “obvious.” Most designers would immediately answer; “yes” sensory fidelity will increase human performance. This is partially due to the logic of simulator design (e.g., Hays & Singer, 1989; Rolfe & Staples, 1986). It is assumed that the closer the simulator is to the “real” thing, the better the training. But does the “obvious” value of sensory fidelity hold true when one considers augmenting human performance in general? When one thinks of plane, tank, or car simulators, the assertion that increased sensory fidelity improves human performance seems to have face validity. If someone is trying to learn motor sequences, it makes sense that practicing the actual sequences would be better than reading about them and imagining the motor sequences. But does it follow that the sensory fidelity or vividness of VR systems would generalize to an overall improvement in human performance?

What does existing research say? Research on the value of sensory fidelity using previous media like pictures, film, and video has produced inconsistent results. For example, there is little support for the notion that more vivid messages are more memorable or persuasive (Taylor & Fiske, 1988). It also appears that sensory vividness interacts with individual differences. For example, the sensory vividness of training materials interacts with the ability of students. In one experiment using pictures and videos, increased sensory fidelity assisted students of low ability but provided no assistance to those of higher ability (Parkhurst & Dwyer, 1983). Existing research on instructional training and simulator design is not uniformly supportive of the ideas that increased sensory fidelity improves learning or performance (Alessi, 1988; Hays & Singer, 1986; Wetzel, Radtke, & Stern, 1994). Research findings like these offer lukewarm or negative support for the value of sensory fidelity.

The concept of selective fidelity

Does this mean that sensory fidelity has no value for human performance? One also has to ask a more basic question: Is any increase in sensory fidelity necessarily valuable? Increasing sensory fidelity provides more information, but not all the information is relevant to the user’s communication goals or tasks. In some cases, the best way to use media to train someone involves reducing the amount of information. For example, we often use maps or schematics of objects — like engines or human internal organs — rather than pictures. The reduced information of the schematic helps the user detect the relevant information such as the location of various components. Learning a skill (e.g., a doctor’s reading of chest X-rays) sometimes involves acquiring the ability to pick out
relevant information from a field of noise and irrelevant data. Interfaces may reduce or alter the sensory fidelity of the image to selectively highlight the relevant cues. This example suggests that human judgment often involves learning how to select a limited set of sensory cues and ignoring much of the other sensory information.

Assessing the design value of some specific aspect of sensory fidelity is not always clear or obvious. We don't always know how the mind uses various sensory cues. Consider the following design decision: Should designers of a driving simulator simulate ambient “street and engine noise”? Will street and road noise increase or decrease the performance of a novice driver? Some decisions are easy: Increasing the sensory fidelity of steering wheel dynamics is clearly more important than increasing the fidelity of street and engine noise. But what could be gained by adding street and engine noise? A number of cognitive issues might be involved about a decision involving street noise. For example, there is the question of the user’s attentional capacity: a novice driver is already bombarded with more information that he or she can handle. There is a question of information relevance: street noise might be just that, noise. It might carry little informational value. On the other hand, the changing acoustics of the tires on the road or wind noise as the car turns might provide some unconscious information about the automobile’s velocity or attitude. For example, there is ample evidence that car drivers use the sound of their car to detect changes in its performance. So even when assessing the value of a detail like auditory simulation of street, engine, and road noise, its value for human performance is not clear. While there is some valuable research (e.g., Gibson, 1966; 1979), we still know too little about how humans use sensory cues to assemble cognitive models of environments.

But my brief discussion of the issue of sensory fidelity still has not addressed the larger question of intelligence augmentation: Can a medium’s level of sensory fidelity ever increase human intelligence? Take my example of the car simulator above. What if we had the perfect car simulator, one that would reproduce every sensory detail of car driving: the feel of the steering wheel, the 3D visual world rolling past the windshield; the rattle of the doors and the boom of the wind rolling over the car body; the smell of the plastic car interior, etc. At its best, such a simulator would do nothing more than simulate what you probably experience every day—driving a car. Would this augment human intelligence? The fellowship of car drivers stuck in traffic jams all over the world would certainly shout, “No!”

Before we rush to judgment that something like sensory fidelity has little to do with augmenting human intelligence, we should remember one thing. Virtual reality is not really about reproducing reality. So my car simulator example leaves out a large segment of virtual environments. Simulation does not always mean reproduction. In fact, few media try to reproduce reality; rather they select and amplify certain parts of human experience. Consider the last movie you saw. Was it “realistic”? Sure, the stroboscopic illusion of visual motion flowing on the screen had a certain level of sensory fidelity. But that visual sensory realism was attached to a camera. Through camera movements and zooms, your “augmented” vision traveled through space. It sometimes occupied positions in space that you rarely occupy. Some moments you saw the scene through the eyes of one character, then, suddenly, through the eyes of another. Is this movement from one human identity to another realistic? Through editing, your “augmented” vision jumped around unrealistically through space from one scene to another, from one place in time to another. Is this realistic? In fact the whole format of the movie medium selected, abbreviated, and amplified all manner of human experience. The experience of travel, love, death, anger were all condensed and funneled through the medium. The medium may have simulated how we think, rather than simulated reality.

Do such codes and media augment intelligence? At some point in our history, they probably did (Donald, 1993). Can the further augmentation of human experience and training possible—or a least, thinkable—in some advanced VR system augment human intelligence? Maybe. But we will have to better understand the psychology of communication and the way to encode and deliver information. Through this we might achieve the goal of intelligence augmentation. We might be able to support more of the mind’s cognitive models, so that human information processing can be increased in ability, complexity, and capacity. The work on human creativity and problem solving suggests that a medium for augmenting human intelligence will be based more on our understanding of how we use sensory information and imagery to encode, think, and problem solve (e.g., John-Steiner, 1985) than by simply increasing the power of a graphics supercomputer. But the illusions of the graphics supercomputer may give us a means to explore how we encode, think and problem solve.

**HOW WILL DESIGNERS BETTER DESIGN MIND TOOLS?**

The worldwide effort to rapidly develop virtual reality and other advanced interfaces is motivated by a desire to augment human intelligence. Ideas related to intelligence augmentation have also permeated the culture. In the United States this desire is wrapped up in long standing cultural beliefs about technology and human perfectibility (e.g., Marx, 1964). In this article I have also tried to show how the design hypotheses propelling VR technology are part of a fifty-year effort to augment intelligence. Because they are central to the conceptualization of advanced media like VR, some of these hypotheses will continue to propel design for the next 50 years. In the vision of Vannevar Bush and his intellectual progeny, the computer will generate unique cognitive technologies, cognitive environments that might free the human mind by enhancing its operation. One thing is clear at this point. Research in the design of virtual reality systems will
attempt to push the envelop of human intelligence by creating new tools to amplify, augment, and adapt cognitive processes.

How will designers apply these principles to build mind tools like VR? Until now, the work has been guided by the single-minded pursuit of increased sensory realism and increased interactivity. To support this effort, research teams have carefully studied perceptual psychology so that they could build an interface that provided the right sensory cues (National Research Council, 1996). But as I have shown above, this might only carry us so far. At the next stage, it will be necessary to better understand the modular structure of the mind. Thought processes in general, and not just perceptual processes, will need to be disassembled so that designers can consider how a combination of hardware and software might better support specific thought processes. We will have to better model thought processes, before we can build engines of thought. But it is also possible that the opposite may be true, that trying to build mind tools might tell us something about the mind. Psychologists, such as Stephen Ellis at NASA's VR lab, believe that VR technology can provide insights into human perceptual processes. In the past the accidental discovery of various perceptual illusions by artists sometimes helped illuminate human space perception. It is likely that the building of mind tools and our understanding of the mind will proceed through stages of mutual advancement. As in quantum physics, where intellectual advancement is often predicated on the building of better tools like larger atom accelerators, designers may be entering a period where the design of new interfaces is directly tied to advances in our understanding of the human mind.

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Beyond Cosmetics

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ABSTRACT

The central part of an industrial designer's responsibilities is the business of translating a concept, or idea, into its material representation. This representation, or product, is characterized by its functional, aesthetic, economic, technical, and ecological qualities and others more. It is therefore necessary for any designer to understand all the factors involved in the synthesis of such a design, and-beyond understanding-to skillfully orchestrate each of these factors for maximum effect and complete harmony. In this article I will show that we are far from understanding and even farther from mastering the most important aspect of design: human-to-product-to-human communication. Next, I will present my thoughts about the direction designers need to explore unless they are prepared to surrender our profession to others.

Keywords

Interface, senses, communication

BACKGROUND

When humans engage in a natural activity such as eating, all our senses participate. We use vision to select the most desirable piece, we touch it and receive tactile information. Liquids or solids inside or the removal of a shell will produce a variety of sounds. Our olfactory analysis yields additional information, and at last, our gustatory sense produces yet another type of input. Every single sense performs a number of tests on our food, at various stages of our interaction with it. A single failed test will lead to its rejection, voluntary or involuntary; before, during, or long after we ingested it.

During the past four million years human survival depended upon a proper and continuous supply of nutrients (picked or hunted), our appropriate social interaction with friend or foe, and our proper response to environmental conditions. Furthermore, our capability to predict future events of nutritional, social or environmental significance would become the foundation of what we now call intelligence.

In order to respond to or predict these survival factors we extrapolate past experience into the future. Experience is processed information which we received through those five tiny windows into reality that we call our 'senses'. Much important information from the outside world does not reach us. No natural sensors exist in humans for ultrasound, ultraviolet light, X-rays, radioactivity, magnetic fields, neutrinos, or most chemical and toxic substances. Our senses supply us with a severely limited image of the world. Our failure to use all the available sensory information could be detrimental to our survival.

The advent of human-made artifacts does not reduce our need to carefully examine our environment. Life has not become less dangerous since we started to mass-produce objects! Our senses produce data no matter whether our current environment or the things in it are natural or human-made. In our interaction with other human beings—which is mostly still that of our prehistoric ancestors—we certainly employ all our senses. Yet when it comes to designing products, designers seem to believe that the visual sense is the only one that matters.

Even considering the visual impact of our products alone, most of a designer's activity is inaccessible to rational argument. What little rational grasp we have on aesthetics we owe to long-dead Greeks or, more recently, to our study of product semantics which is still in its infancy. Industrial Designers still operate in the dark ages similar to the barber-surgeons of the dawn of the medical profession of five centuries past. Designers diagnose mysterious corporate diseases such as chronic innovation anemia; they wield magic-marker wands, develop marvellous potions in form of sleek, new, glistening products to cure all corporate ailments. They speak in strange terms which no decent engineer ever understands. Finally they charge what is perceived as an enormous fee, then rush to find their next corporate prey. Do they ever stay around long enough to monitor the success or failure of their keen ideas? Have they developed scientific means to measure and predict the results of their therapies?

Products today don't breathe, moan, grow, wiggle, smell, sniff, withdraw, or offer themselves. Designers create attractive-looking corpses. The designer-undertaker! Of course, products have acoustic, tactile, olfactory and gustatory qualities! Every product does, but these qualities occur as a random consequence of a designer's visual-aesthetic or technological decisions. It is my understanding, that the better we address a person's communication needs, the better this person will be able to use the product, and the more satisfying will be this person's experience with the product. Needless to say this means sales. And jobs.
The term interface implies the bi-directional flow of information between the two parties involved: humans and products. As much as we use our senses to receive incoming information, we transmit information as well, which is available to somebody or something else. As long as designers ignore this part of the information exchange by not equipping our increasingly complex products with the appropriate sensory devices and intelligence, the success or failure of a product in the market happens only as a consequence of our gut-feeling visual-aesthetic decisions! This is not enough for us to become truly respected partners in the product development and innovation business.

Speaking about human interface and communication, our view of the subject needs to be extended beyond our discussion of the five senses. Information flowing in two directions, times five senses equals a total of ten communication channels.

To this we need to add yet another concept. It is not immediately obvious, but if you think about it, humans are only partially equipped with active transmitters. Consider the visual information carrier. Lightning bugs and LED’s transmit light for communication purposes. Humans usually don’t glow in the dark or shine light beams at each other from a pit in their foreheads. Humans modulate existing ambient light by means of the clothing they wear, their body movements (e.g. body language), or by artifacts they carry or use. Human transmission of visual information is passive.

Our acoustic transmitter, on the other hand, is of active nature: our voice, our stomach growling, clapping our hands, all transmit sound actively produced by our bodies. So for each communication channel we will need to distinguish between active and passive transmitters, as well as active and passive receivers of information.

At this point I will proceed to discuss some of the specifics regarding each of our ten communication channels.

**THE VISUAL TRANSMITTER OF A PRODUCT**

Every visible detail of a product transmits visual information. Form, size, proportions, color, texture, reflectivity, every single radius all are information transmitted into the environment. A human recipient will interpret this information as a product’s statement about its purpose and functions, its value, its longevity and the gain of power, status and satisfaction it promises to bestow on its happy owner.

While the passive visual qualities of our products today are determined by industrial designers, their active visual features too often materialize beyond our control. Lights, LED’s, displays and LCD-screens are developed by engineers. At best we are given a late opportunity to shroud them in a pretty enclosure. That’s product cosmetics, not industrial design. If we educated ourselves about the technological possibilities existing today, we could do a much better job using these active visual elements for communication purposes.

LED’s can be on or off. They can vary their intensity, color, blinking rate, location, apparent size. A single LED blinking more rapidly as somebody approaches subconsciously informs the burglar about the fact that his presence has been detected. A product’s visual transmitter provides most of the information during its first encounter with a potential human user. But in many situations is of limited use:

* in the absence of light
* over large distances
* in the presence of visual obstacles
* when the user is blind, sleeps, or is unconscious
* when the user happens to look the other way
* when a detail is too small for the user’s optical resolution.

**THE VISUAL RECEIVER OF A PRODUCT**

Designers seem to be ignorant with regard to the technological possibilities of artificial vision. If our products could see us and process the data intelligently, we would avoid much frustration and reduce user complaints. A few examples exist where machine “vision” has been implemented, e.g. the automatic doors in public spaces such as shopping malls and airports. We could envision more advanced applications where a product might identify the user and adjust its own user interface based on its prior “experience” with the specific individual. We could save energy by developing lighting systems which could sense the presence and body orientation of human beings to control the location and amount of light presented. We could envision vending machines which change the location of their user interface according to the body height of their users. All sorts of devices, cars, furniture, public transportation systems, medical equipment could use artificial vision to adapt themselves to their users’ special characteristics.

**THE ACOUSTIC TRANSMITTER OF A PRODUCT**

Objects, animals and human beings generate and transmit acoustic signals which any human counterpart is able to pick up and interpret. The human brain detects minuscule changes in pitch, dynamics, intensity, composition and direction of sound. When bypassing the conscious portion of the brain, its older regions trigger involuntary physiological and biochemical reactions to sound, such as shock, fright, or alarm. Beyond the spoken word there is a huge region of untapped communication potential. In an era when cross-cultural and cross-national trade require products to supply printed instruction in a myriad of languages, it is about time we acknowledge the superiority of non-verbal communication to reading and interpreting volumes of printed text.

Today however, even the most sophisticated among our products generate sound of the most primitive quality imaginable. Products costing thousands of dollars sound silly beeps with little information value. A telephone signaling each keystroke
with a different sound provides an acoustic melody as supplementary feedback. This adds redundancy to the tactile and visual feedback used in the operation, thus enhancing the reliability of our interaction with the product. A car produces many different sounds informing its driver about its current acceleration, mechanical stress, maintenance required. It doesn't come as a surprise that people are so emotionally attached to these roaring ecological disasters. Clever designers will soon manage to redesign the venerable tea kettle, equipping it with an LCD temperature display, plus another silly beep!

Humans are equipped with a wealth of acoustic transmitters. Verbal communication is only the most obvious and sophisticated use of our voice. Singing, whistling, humming, clapping one's hands, coughing, sneezing, blowing one's nose, yawning, the growl of an empty stomach and other utterances of the digestive system as well as other non-verbal sounds we manage to produce with our voices are extremely important acoustic carriers of information which we have yet to understand and exploit.

As we are used to producing sounds and to receiving acoustic messages from other human and non-human beings, we should expect communication between humans and products to improve dramatically if we were able to give our products the benefit of verbal and-more importantly-non-verbal sound transmission and reception. In a shrinking acoustic environment it will be the designer's task to craft sound for communication purposes. Non-verbal sounds are particularly well suited to enhance the product-to-human communication and to reduce the amount of paper otherwise necessary to convey written instructions in the many languages spoken in the global marketplace.

THE ACOUSTIC RECEIVER OF A PRODUCT
Humans have learned to interpret many of the non-verbal sounds produced by animals, other humans and by nature in general. Our products have not. We produce voice-control products which react to the spoken word. A different language spoken by a new user requires new training, whereas a certain type of grunt could have the same meaning-globally. A baby crying alerts mothers in any culture. Many products could benefit by feeding tactile status information to the user.

Even the absence of tactile information could improve the interface, e.g. by simply not displaying the non-option keys in a keypad. Non-option keys are those which are temporarily or permanently disabled, e.g. the video disk buttons on the remote control of a home stereo system in which no video disk player is present, or the function keys on the computer keyboard when the software doesn't use function keys. The designer's concept of the tactile information carrier needs to be extended beyond that of mere perception of surface pressure on our fingers. Tactile information is stomach pain, the sensation of gravity, our perception of acceleration and deceleration, heat, or the lack of it. Tactile transmission is both passive and active. Passive is the "feel" and "touch" of a surface or the force response of push button. Active tactile transmission is the vibration alert of a personal pager.

THE TACTILE RECEIVER OF A PRODUCT
This channel is believed to be well-used and understood. Most products are handled by their human users, many have buttons, keys, switches, slide controls, lids that flip, locking mechanisms. In all these cases the product responds with a pre-determined reaction programmed into its hardware and/or software. The response is the appearance of type on the computer screen, a musical sound, the lamp lighting up, the vending machine producing a can. The typical response is crude.

Humans are aware of many different meanings of touch. A touch can provoke friendly feelings or fear, it tells us about our counterpart's intentions or mood. A collision between humans on a sidewalk can be accidental or an act of aggression preceding a fight or robbery attempt. Products do not differentiate between "friendly" or "unfriendly" key pressures. They all fail to interpret information about the user's mood,
intensities, or state of mind readily available but hidden in subtle changes of body temperature, skin moisture, hand pressure variation and other types of modulation of the tactile signal. What if products were given a soul, an intelligent way of communicating with us via the tactile channels, making them truly "touching"?

THE OLFAC TORY TRANSMITTER OF A PRODUCT
In nature, odors serve many purposes. Odors transmit information about the presence of a fruit or its edibility, about a sexual partner's proximity or state of readiness, at least in the animal world. Odors in the world of human-made products attract, entice, repel, deceive. We rarely use odors to inform, educate, alarm or guide. Smell in some products is unintentional. A car smells when oily residues contact hot areas on the engine or exhaust system. These oils burn, and their fumes inform about the presence of heat or oil leaks. As technologies evolve, gaskets won't leak and engines shut down automatically. Our olfactory world is losing its richness as fewer and fewer things smell. What a loss! Designers could bring back much of this richness by making themselves aware of the message value of odors. Those among you who have read Perfume by Patrick Suskind know what I mean.

THE OLFAC TORY RECEIVER OF A PRODUCT
Scent molecules travel via the air or other media. Their range is, theoretically, unlimited and depends only on the sensitivity of the olfactory receptor. Few products today have olfactory receptors. Smoke detectors do, gas detectors do, as well as "Breathalizers" which detect alcohol vapors in human breath. Much more is technologically possible. Doctors and nurses smell a disease on the patient's breath, e.g. the smell of acetone hinting at the presence of diabetes. Not only diagnostics evolve, gaskets won't leak and engines shut down automatically. Our olfactory world is losing its richness as fewer and fewer things smell. What a loss! Designers could bring back much of this richness by making themselves aware of the message value of odors. Those among you who have read Perfume by Patrick Suskind know what I mean.

THE GUSTATORY TRANSMITTER OF A PRODUCT
Smell and taste are closely related. Both are of chemical nature and, consequently, more difficult to analyze, process, store, reproduce or transmit than their visual, acoustic and tactile equivalents. The olfactory and gustatory qualities of products are essential to a human being's understanding of the material world, as every baby will attest. Babies need to see, listen to, feel, smell and taste everything in their environment, in order to establish a mental model of the objects surrounding them. Products which don't smell or taste deprive people of a learning experience. Their mental model of the product is incomplete. No future smell or taste will ever trigger memories of the product or of the circumstances present during its earlier utilization.

We learn to compensate for olfactory (and gustatory) deprivation by relying on our visual, tactile, or acoustic senses, but this represents an artificial reduction of information humans have learned to expect from their natural environment. No doubt, gustatory information is of greater importance in products which are intended for human ingestion. It is the final safeguard in a series of tests we perform on food before we swallow it. However, we do lick stamps whose taste is enhanced with mint flavors. We do chew on pencils and pens, and if this were to be considered unhealthy, an unpleasant taste should be employed to tell us not to. Some products could be protected from a small child's gustatory exploration or interaction of any kind, if they tasted real bad.

A product's gustatory transmitter is passive. It relies on the presence of human saliva for the "taste" molecules to dissolve and travel towards their corresponding receptors.

THE GUSTATORY RECEIVER OF A PRODUCT
Do products have taste buds? I can't think of any, but what if they did? Certainly, all products which are handled or touched by humans would have the opportunity to taste them. Would our communication with products improve? Become easier? More convenient? How about our learning experience? The human user is rarely considered to be a food item to our products, so is there any use for this channel?

If we think of taste in a more abstract way, we may determine that there is information available on the skin of a human user which could be sensed and processed by a product. Sweat produced in the sweat glands embedded in our skin does change its chemical composition in response to factors such as stress, nutrition, health. Diagnostic medical products or clothing worn on our bodies could be developed to taste the byproducts of our metabolism and inform us about our health condition. Additional applications are thinkable but require many an open mind before they could lead to an improved human interface.

CONCLUSION
More research is needed to fully understand the roles that sound, touch, smell and taste play in product design. Much more work is needed before we will begin to understand the nature of aesthetics as a holistic experience of vision, sound, touch, smell, and taste cooperating in a harmonic way to convey a much more complex message than any product in existence today. Our most immediate need is to comprehend the communication character of our decisions with respect to the visual, tactile, acoustic, olfactory, and gustatory qualities of the products we design. We need to develop acoustic, tactile, olfactory, and gustatory languages analogous to product semantics. Next, we need to learn how to accomplish their harmonic interaction. Intelligent Design Beyond Cosmetics is our chance to stay in business. Let's not miss it.
Appendix A

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Appendix B

Funding Options. An Example from NSF

This is a National Science Foundation example of funding opportunities for design students and faculty in the development of research programs.

National Science Foundation Funding Opportunities in Information Technology, Culture, and Social Institutions

October 4, 1996

Dear Colleague:

The development of information technologies and new types of digital content in all aspects of society has far exceeded our understanding about how these new technologies have reshaped social organization, work life, interaction patterns and culture. In response to this shortcoming, the Computer, Information Science, and Engineering directorate (CISE) and the Social, Behavioral, and Economic Sciences directorate (SBE) as well as the Education and Human Resources directorate (EHR) are encouraging multidisciplinary proposals for research at the interface of social science and information technology. Proposals may be submitted on standard forms (see the Grant Proposal Guide, NSF 95-27) to existing programs (see the Guide to Programs NSF 95-138) as this notice calls attention existing funding opportunities.

The proposed research should aim to advance our understanding of how information technologies shape and are shaped by the social and cultural dimensions of groups, organizations, institutions, and societies. The driving force for this interaction is the widespread proliferation of distributed computing with vastly increased processing, communications, and storage capabilities. Research should seek to understand the impact of new forms of digital content accessible to wide segments of society as well as national and global institutions such as nation states, multinational corporations and financial institutions. The methodological approach should be appropriate to the unit of analysis and research questions. For example, a study of the impact on culture might focus on understanding how people learn about and use information technology in real-life situations, or on the interacting technological, social, and organizational factors that facilitate or impede productive use and learning. A study of the impact of information technology on nation states might focus on the changing nature of sovereignty. Especially welcome are proposals that aim to develop general explanations, through grounded theory or other empirical approaches, these areas Social science contributions to the design of systems affecting large segments of the population are also welcome. Examples include cultural, economic, political, sociological and spatial factors that should be incorporated into systems designed for ordinary citizens.

We are interested in a broad range of studies on the social and cultural dimensions of new information technologies. For example, specific examples of possible research topics are listed below:

- Ethnographic studies of how information technologies legitimize people's identification with communities, and how human-computer dynamics in work-places structure the work process to affect productivity.
- Studies of the spatial and geographical implications and behavior associated with the spread and use of information technologies.
- Research to develop theories, methods, concepts, and principles that provide foundations for making large-scale, collaborative, content-rich applications effective in practice in their organizational and social contexts.
- Research that examines the operation, impacts, and usage patterns of organization-scale computing, content, and collaboration technologies with the aim of feeding back resulting knowledge into new technologies and new approaches toward integrating them in context.
- Research that examines the use of digital library resources in education, science, and technology. How does the immediacy and richness of digital; libraries and their associated tools change then nature of research and education? How does the social conduct of science change and how can these changes best be accommodated?
- Studies of the research, design, development and implementation processes that bring new information technologies into existence, and the influence of such technologies on creativity, productivity, and social life in a variety of settings, including schools, work places, and homes.
- Research to examine and evaluate ethical norms in the development and use of new information and communication technologies.
- Research to facilitate the development of laws and law-like rules regulating access to, use of, outcomes of using information technology.
Planning grants of $20,000 - $50,000 for 12-18 months are available to assist in the preparation of multidisciplinary proposals that might require collaboration between social and behavioral scientists and their counterparts in computer science and engineering. For example, social scientists may want to work with researchers in large, multidisciplinary NSF-funded projects focusing on information technologies such as the digital libraries, collaboratories, partnerships for advanced computing infrastructure (PACI), very high-performance network services (vBNS), Engineering Research Centers, and Science and Technology Centers. (see www.nsf.gov, www.cise.nsf.gov and www.eng.nsf.gov) Other examples of possible research in the area of information technology and culture can be found in the workshop report "Culture, Society and Advanced Information Technology", available from the Computing Research Association (info@cra.org, fax: (202) 667-1066) or from the American Anthropological Association (peggy@mhs.compuserve.com, fax: (703) 528-3546), and on the World Wide Web at http://cra.org/Reports/Aspects/. The foundation hopes to make about 10 awards in FY 1997 whose average duration is about 2-3 years and whose average total award size is $50,000 - $500,000, subject to available funds and proposals of high scientific merit.

Prospective applicants should consult one of the program officers listed below for relevant deadlines and target dates and application procedures.

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Appendix C

Design and Management of Information Networked Technologies (DMINT). An Example from NCSU

The faculty and administrators of North Carolina State University at the suggestion of industry leaders began investigation into the access to information resources through the use of electronic media. A discussion meeting was called on August 14, 1994 by Walter Wiebe, Director of Program Development at MCNC. The purpose of the meeting was to outline a program to encourage the development of multidisiplinary research in information technology. Attending the meeting were Richard Lewis - Dean of College of Management, Marvin Malecha - Dean of School of Design, Ralph Cavin - Dean of the College of Engineering, Alan Blatecky of MCNC, John Fjeld of IBM, and Wayne Clark of Cisco Systems, Pat Rand - Assistant Dean for Research.

Out of this meeting came an agreement to:
- Set up working groups.
- Develop a multidisiplinary setting.
- Design an “education program for the Information Age”.

Rapid changes in educational infrastructure and information access are resulting from the development of digital communications networks such as the National Information Infrastructure (NII), North Carolina Information Highway (NCIH), North Carolina Research and Education Network (NC-REN). The physical infrastructure is a latent tool for improved communications, but it needs to be creatively designed and managed in order for its effectiveness and value to be maximized. How is the United States going to ensure that it has the educational infrastructure and educated people to design, develop, operate, maintain, and use the National and State Information Infrastructure? In response to the need for improved design and management of the information on such networks, the Design and Management of Information Networked Technologies (DMINT) group has been formed at North Carolina State University.

The DMINT group, with the support of the Deans, began to meet every Friday for two hours to discuss and develop goals and target research initiatives. During the first six months the following goal and objectives were developed.

Mission Statement:
The purpose of the Design and Management of Information Networked Technologies (DMINT) group is to encourage and promote research and scholarship in fulfilling the University’s role as a world leader in discovery and dissemination of new knowledge regarding networked digital media. The DMINT group provides leadership through service to investigators and their sponsors in the discovery, dissemination and application of new knowledge.

Participants in the DMINT group will grow and change over time. The group currently includes faculty and staff from various departments in the following academic units:
- School of Design, NCSU
- College of Engineering, NCSU
- College of Education and Psychology, NCSU
- College of Management, NCSU
- NCSU Libraries

Industry Affiliates and Sponsors in the DMINT group will also grow and change over time. The group currently includes:
- MCNC
- Center for Networked Information Discovery and Retrieval (CNIDR)
- Cisco Systems

Goals:
- Establish the Design and Management of Information Networked Technologies Group and North Carolina State University partnership as a national leader in the design, development and management of networked information systems.
- Develop academic and research initiatives that establish university, government and industry partnerships.
- Create and maintain an operational model that incorporates participant interest with resources and opportunities pursuant to stated goals.
- Establish alliances and partnerships with federal and state government, private sector and industry to promote and secure support for programs.
- Promote opportunities for students to pursue their interests in digital media through participation in academic and research programs provided by industry and other sponsors.
Engage the citizenry of North Carolina in the identification of information services needs and solutions.

Strategies:
- Assemble multi-disciplinary teams consisting of design, computer science, engineering, education, library science, and management, with expertise coming from academia, industry, government and others.
- Establish Design/Development teams that define program/functional objectives.
- Develop curricular resources and research projects as required to meet goals.
- Solicit through a public forum suggestions regarding information service needs.
- Demonstrate the potentials of this medium through presentations to the public.

Many different ideas were developed out of the DMINT group. These thoughts and ideas in some cases became the working outlines of projects to be initiated by the University faculty. Many of these ideas have become real projects in the University. Ideas for the development of a virtual museum became a reality with the North Carolina Museum of Art. ArtNet can be seen at http://www2.ncsu.edu/NCMAI. The ideas for an advanced intelligent interface using animated pedagogical agents to assist in access to information resources became SmartGuide and Intellamedia.

The ideas are also fostering a change in the educational structure of the University. Out of this multidisciplinary interaction among faculty at the University has come the idea for a multidisciplinary Masters degree between Design, Engineering, and Management. The School of Design is creating a multidisciplinary Ph.D. program that is currently being reviewed by the University of North Carolina System and can become a reality by 1998. The opportunities for multidisciplinary research are increasing and we need to work hard to break down traditional barriers and allow it to happen.

DMINT Advisory Council Charter

The purpose of the Design and Management of Information Networked Technologies (DMINT) and the DMINT Advisory Council is to encourage and promote research and scholarship in fulfilling the University's role as a world leader in discovery and dissemination of new knowledge regarding networked digital media. The DMINT group provides leadership through service to investigators and their sponsors in the discovery, dissemination and application of new knowledge.

The Advisory Council is to advise DMINT on policy and programmatic matters related to strategies and tactics through which DMINT may achieve its goals. The membership of the Advisory Council is intended to be broad and diverse.

Affiliates and Sponsors in the DMINT group will increase and change over time. Constituencies include the following: research and scholarly communities who are the end users of the networked information, organizations and individuals that need digital media design services, industrial organizations that develop and provide relevant technology and services, and experts in networked information and computer science who provide technical guidance.
Appendix D

A Visualization Research and Outreach Program. An Example from NCSU

Design Research Laboratory
School of Design, North Carolina State University

Executive Summary

The proposal seeks to establish a University program, within the Design Research Laboratory, for research and outreach in advanced visualization (applied virtual reality). The planned multidisciplinary program will seek to synthesize existing and future knowledge and methodology about the use of visualization technology in information transfer. This will create an understanding of how applications of this technology apply to a real world context and act as a conduit of knowledge and information transfer between the University, inventors of technology, the design and engineering industry, community colleges, and K-12. The visualization research information produced by this program will be applicable to many different situations such as digital imaging, design tasks, collaborative design processes, distance learning, development of a virtual classroom, and information about the design and management of complex systems needed in 21st century industries.

Visualization must become a fundamental tool, not only for “post-process” presentation graphics, but must be incorporated as an integral part of the entire process of design analysis, description and presentation. With the computer’s ability to generate ‘virtual’ images and environments from raw data and imagined scenarios, a more effective communication can be made of the uniquely human capacity for creative and analytical thought. Visualization applications afford us new tools with the potential to visualize and communicate during the evolving process of design. Manufacturing, the building products industry, and design teams in all sectors of the economy are in need of visual techniques to manage the assimilation of complex concepts and ideas as they evolve.

Devices that connect with the visual, tactile and aural senses of the user can provide the interactive interface essential to the experience of a virtual reality. Individuals in design and engineering firms are increasingly interacting from remote locations and there is an ever increasing need for effective applications to facilitate collaboration in highly interactive groups. Applications of visualization technology for group collaboration will be important in the development of the next century’s virtual classrooms. Distance learning will rely heavily on new visualization methods for transforming textual material into images and sound for greater understanding of concepts and methods.

This program will seek to find new research opportunities for NCSU faculty and staff across the University as well as assisting in the development of resources that can be applied through the industrial extension service to related projects. Multidisciplinary research opportunities created by the program will assist in fostering related Master’s and Ph.D. programs. Sponsorship of the program will begin through the University and within five years transition to the government and private sector for future support.

The Design Research Laboratory will establish links to industry, through a consortium of industry leaders. They will participate in the development of avenues of research which will benefit both the respective industry and the University community. There is ample evidence in industry that the most innovative companies specializing in advanced technologies and software development place design at the front end of decision-making processes and that there is growing need for design research and researchers.

Suggested Goals of Visualization Program

• Establishment of a working knowledge of what is the state-of-the-art in digital imaging, animation and multimedia.

• Development of techniques and methodology for managing data structures that result in desirable information densities and formats in digital imaging, animation and multimedia.

• Develop a better understanding of the communication dynamics involved in information transfer, including group dynamics, distance learning and multimedia presentations.

• Develop an understanding and methodology for the process of manipulating information in its various formats.