Design Research
Building the Knowledge Base

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INTRODUCTION

"Research" in design has a long but not very robust history. Individuals have published on the subject almost from the time design was recognized as something to be taught (engineering and architectural design theories have been in the literature since Roman times). Yet, despite exceptional efforts by some individuals, the degree of interest in research among the design disciplines has been quite uneven, ranging from more than a little in engineering design, to some in architectural and product design, to not very much in the fields of design most closely associated with the arts and crafts. In sum, in comparison to what is normally encountered in the sciences, humanities and other scholarly disciplines, there has been precious little interest in what might be thought of as "classic" research.

But change is afoot. Events are propelling industries and countries into new economic relationships, and design is being recognized as a critical factor for business success. The result is new interest in the quality of design available, and—more fundamentally—interest in how design can be improved. As export strength commands more attention as an economic indicator, the improvement question becomes very important, its answer imperative.

For developed and developing countries alike, high-quality design is the most cost-effective resource available to improve trade balances. A few good designers using advanced design processes can have dramatic impact on the success of products and services. The obvious inference is that it behooves countries, industries and companies to develop high-quality designers and equip them with high-quality design tools: theory, methods and processes.

Thus, design research. And thus, among design educators, new interest in the nature of design research—especially as it may extend understanding beyond definitions of classic research used by the sciences and scholarly disciplines. In fields where the thrust of work is synthetic rather than analytic, this questioning is not naive. There is value in serious reflection on the most basic questions concerning research. What follows should be interpreted as such an exploration—an attempt to abstract from what we know in the hope of finding new models that may shed light on what we can do in design.

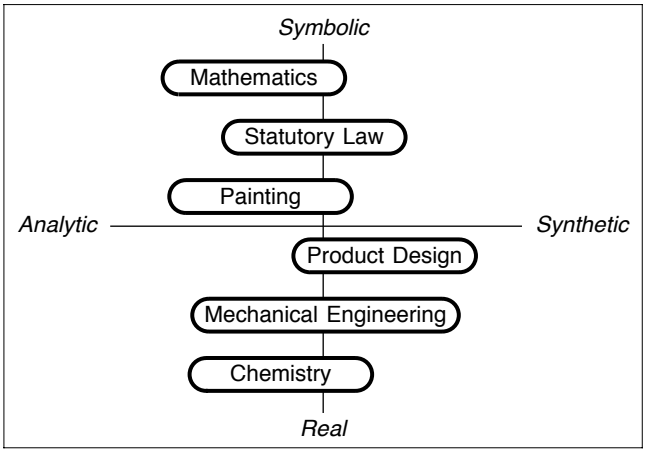


Figure 1. A Map of Disciplines.

THE PROBLEM

Design, as a discipline, is still young (or, perhaps, is a slow learner). At any rate, it has not developed the internal structures and understanding that older disciplines have. Design is not science, and it is not art—or any other discipline. It has its own purposes, values, measures and procedures. These become evident through comparisons, but they have not been extensively investigated, formalized, codified or even thought much about in literature created for the field. In short, there is little to point to as a theoretical *knowledge base* for design. As a result, those who seek to work more rigorously look to scientific and scholarly models for guidance, and we find references to "design science" and examples of "design research" that would seem to fit more appropriately in other fields.

Yet, it is reasonable to think that there are areas of knowledge and ways of proceeding that are very special to design, and it seems sensible that there should be ways of building knowledge that are especially suited to the way design is studied and practiced. To approach these questions, it is probably best to abandon the term "research" for a time and, instead, look at how knowledge is used and accumulated—since building knowledge, after all, is the goal of research.

As a context for thinking about specialized knowledge acquisition and use, a *Map of Disciplines* reveals interesting differences among traditional fields of study and practice. Two axes define the map in Figure 1. Separating the map into left and right halves is an ***Analytic/ Synthetic*** axis. Disciplines positioned to the left of center are more concerned with "finding" or discovering; disciplines to the right are oriented toward "making" and inventing. A ***Symbolic/Real*** axis divides the map again into halves—vertically this time, according to the nature of the subjects of interest. Disciplines in the upper half of the map are more concerned with the abstract world and the institutions and communications that allow people to live and work together. Disciplines in the lower half work with the real world and the artifacts and systems that enable us to operate in the physical, not always friendly, environment.

A sample of disciplines illustrates how the map discriminates. In the upper half, mathematics, statutory law and painting work with abstract, symbolic subjects; below, product design, mechanical engineering and chemistry deal with real world phenomena. Mathematics, painting and chemistry are primarily analytic in procedure; product design is almost entirely synthetic; and statutory law and mechanical engineering achieve something of a balance.

The positionings are, of course, subjective and relative, but they provide a means for gross comparisons on the basis of two very fundamental ideas about content and procedure.

The map is also a means for examining other relationships. Mechanical engineering seems nicely centered between the analytic and synthetic domains, but it is a discipline with subdisciplines. Engineering science, as one of these, would be located on the analytic side; engineering design would be more on the synthetic side. Hierarchical decompositions such as this afford opportunities for leveling or sharpening descriptions. Merging usually levels, moving the result of composition toward the center; decomposing sharpens, disseminating new elements into the quadrants.

Movements of disciplines over time can also be tracked. Through much of its history, painting was concerned with commissioned applications for clients. The trends of the last century moved it radically to the left, and it has become considerably more analytical and exploratory in intent and procedure.

No matter where they are on the map or how they move, merge or diverge, all disciplines build knowledge bases. How they do this is important because it sheds light on the process and offers analogies for design. There is no single means, and the multiplicity strengthens the results.

CHARACTERIZING THE PROCESS

Knowledge is generated and accumulated through action. Doing something and judging the results is the general model. In Figure 2, the process is shown as a cycle in which knowledge is used to create works, and works are evaluated to build knowledge.

Knowledge using and knowledge building are not unstructured processes. They are controlled by *channels* that direct the procedures that are used to do and judge the work. These channels are the systems of conventions and rules under which the discipline operates. They embody the measures and values that have been empirically

developed as "ways of knowing" as the discipline has matured. They may borrow from or emulate aspects of other disciplines' channels, but, in the end, they are special to the discipline and are products of its evolution.

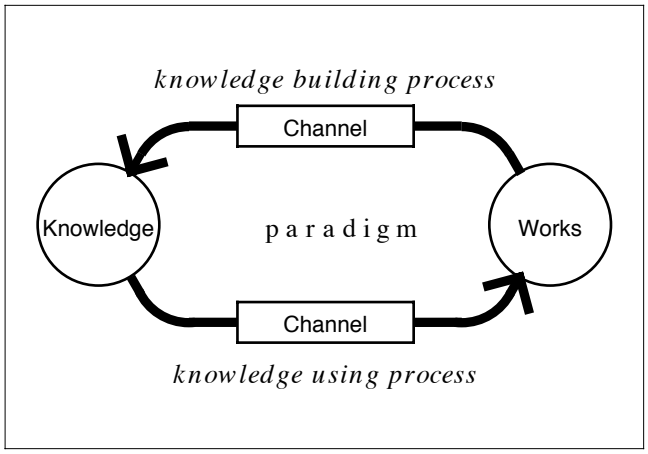


Figure 2. A general model for generating and accumulating knowledge.

The general model of Figure 2 can be extended to a model that fits the dual nature of actions suggested by the analytic/synthetic dimension of the map of disciplines. In Figure 3, this is done with an additional specialization of labels.

On the left side of the diagram, the realm of theory, the model is a paradigm for inquiry. Existing *knowledge,* under the direction of *theory,* is used to generate *proposals. Proposals* are tested with *measures* that verify or refute conclusions to build knowledge.

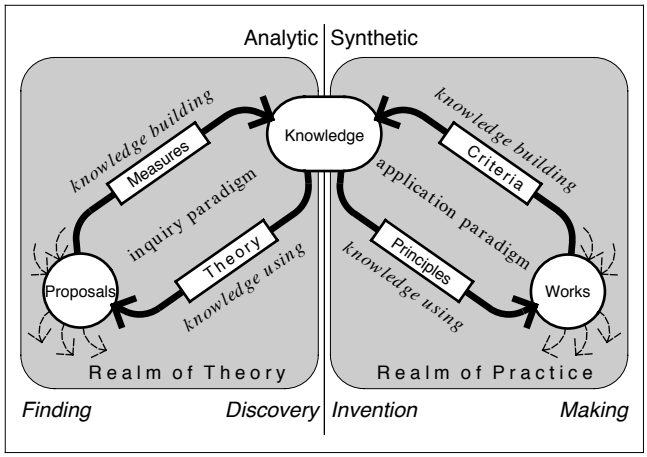


Figure 3. Using and accumulating knowledge in the two realms.

On the right side, the realm of practice, the model forms a paradigm for application. Here, *knowledge* is used through the application of *principles* to produce *works*. Works are judged for their worth as additions to the knowledge base using the *criteria* of the discipline.

Proposals and works also benefit from and contribute to ideas in other disciplines. A more complex diagram would show interdisciplinary relationships. Figure 3 suggests these as dashed arrows entering and leaving proposals and works.

Some Examples

To test the model, Figure 4 shows the sample disciplines of Figure 1 fitted with titles more expressive of their special characters. The darkness of the background suggests the skew of their primary activity to either the realm of theory or realm of practice—darker meaning more commitment.

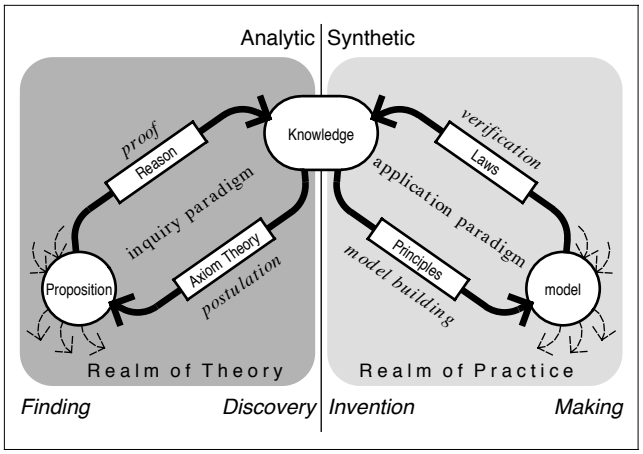
It is hard to find a set of words that optimally fits a discipline—clearly fits it better than any other set of words—and differentiates it distinctly from other disciplines. Such nuance requires considerable variety and subtlety. Fortunately, both are available in English, and at least an attempt can be made. As an example, mathematics, for a paradigm of inquiry, *postulates propositions* using *axiomatic theory* and *proves* them with *reason* to build knowledge. In application, *models* are built with mathematical *principles* and *verified* with the *laws* of mathematics to add to applied knowledge. For better or worse, the other examples in Figure 4 similarly attempt to distinguish differences in procedure, objects of effort and means of procedural control through choices of appropriate terms.

Selectively substituted words bring the generalized model into harmony with a specific discipline. Even though not perfect, they convey meanings well enough to convince. They also supply different viewpoints, a goal for extending our conception of knowledge-building processes in design.

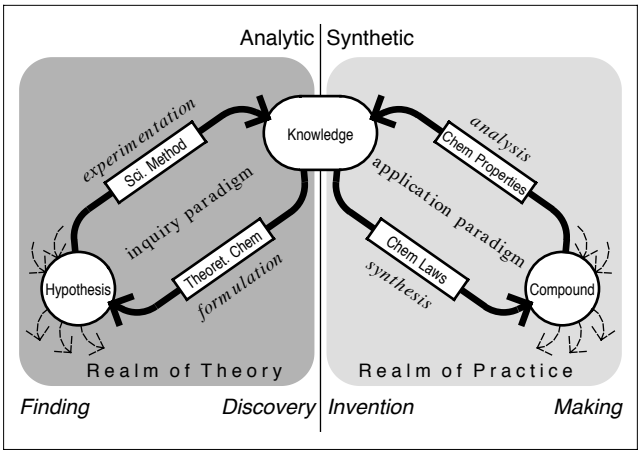
USING AND BUILDING

In the acts of both doing and judging, questions are asked, answers obtained and decisions made. How these are formed is the key to using knowledge successfully to build new knowledge.

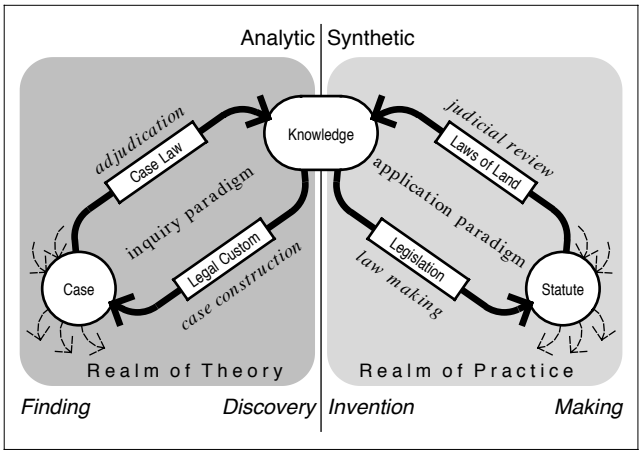
Questions, answers and decisions differ fundamentally in nature from discipline to discipline. They are framed from the value systems embedded in the disciplines. Table 1 suggests some of the these differences using the sample disciplines. Note that the differences are far deeper



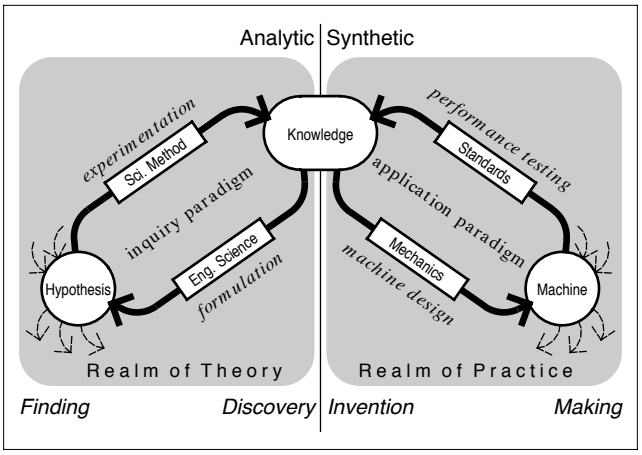
Mathematics



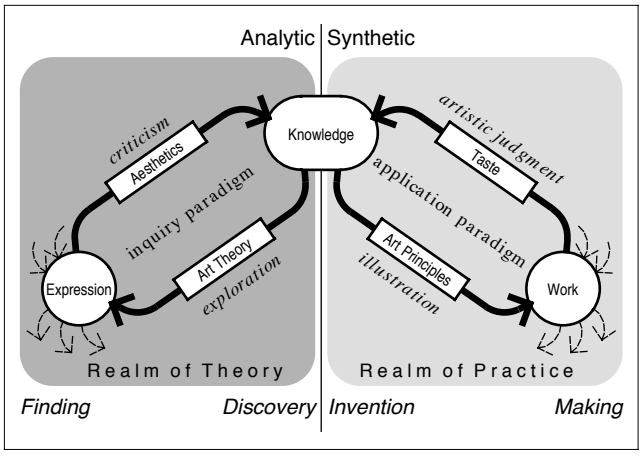
Chemistry



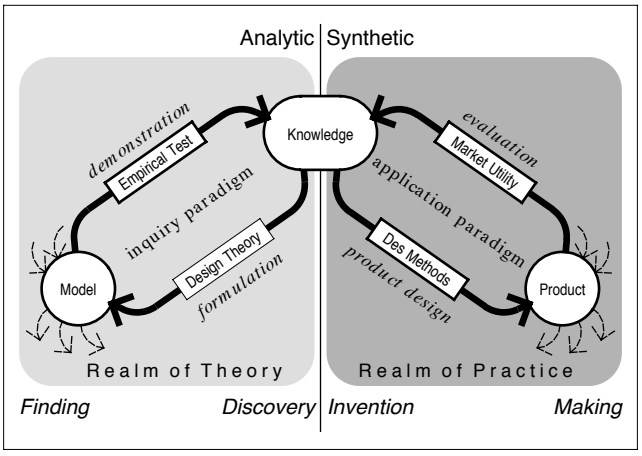
Statutory Law



Mechanical Engineering



Painting



Product Design

Figure 4. Sample disciplines with titles appropriate to their purposes.

than issues of content. They grow directly from the basic values that create the knowledge structures of a discipline. As an interesting derivative of this comparison, it is possible to see through these differences the reason that design is not science or art, although it shares some of the characteristics of each.

The forms of questions, answers and decisions also differ *within* disciplines—between inquiry and application, and between doing and judging. These reflect the difference in purpose between inquiry and application and the difference in process between doing and judging.

For comparison purposes, the processes of using and building knowledge can be expressed as concatenations of question/answer and question/decision mediated through the channel appropriate to the process.

Table 1. Differences in Measures

Domain	*Discipline*	*Measures*	*Source of Values*
Science	Mathematics	true/false correct/incorrect complete/incomplete	reason logic
	Chemistry	true/false correct/incorrect right/wrong works/doesn't work	physical world
Technology	Mechanical Engineering	right/wrong better/worse works/doesn't work	physical world artificial world
Law	Statutory Law	just/unjust lawful/unlawful right/wrong	social contract
Arts	Painting	beautiful/ugly skillful/unskillful thought provoking/banal	culture
Design	Product Design	better/worse beautiful/ugly fits/doesn't fit works/doesn't work	culture artificial world

Consider first the case of inquiry, the classic and most thoroughly discussed process. Here, the form of a question in knowledge using, or doing, is theoretical or methodological, seeking to find understanding of a phenomenon or process important to the discipline. An answer is formed as an evaluatable proposal. For the judging required for knowledge building, the form of question and decision is derived from the discipline's value system, setting a framework for judgment and measures to be used.

On the application side, doing involves questions and answers specific to a work or project that has been undertaken. Questions search for understanding of entities, relationships and contextual elements within the project. Answers embody the understanding in ideas that draw on insights—solutions to problems. Judging, again, draws on the values of the discipline for the kinds of questions to ask and the criteria to make decisions. Questions thoughtfully constructed using these criteria exact decisions that determine a work's contribution to the knowledge base. The contribution, in this case, is the work or aspects of it that, through new syntheses, add to what is known about how the discipline's knowledge can be applied.

A DESIGN PROGRAM

Design (and design education), though young in comparison with many disciplines, has had sufficient time to move from fledgling practice to responsible discipline. And the issues discussed here are now being addressed in many colleges and universities around the world. At the Institute of Design, this self-examination process has led to a reconceptualization of the school's programs, its purpose within the evolving discipline, and its role as an educational and research unit of its university, Illinois Institute of Technology.

Over the last nine years, the Institute of Design has moved organizationally from a department of the College of Architecture, Planning and Design to a college-level unit of the university, moved geographically to new quarters in the university's research institute, and completely regenerated its graduate programs. Since the fall of 1991, the school has offered two graduate programs, one a professional, terminal-degree, *Master of Design (MDes)* program, and one a research program with *Master of Science in Design (MS)* and *PhD* degrees.

Matching the Map

With the insights of the map of disciplines in mind, the new programs merge the previous programs and position the Institute of Design's total offering in a better balance of inquiry and application. The new programs also integrate design specialties to create courses more appropriate for today's needs (Figure 5).

Product Design and Communication Design from the old program are now merged into a single design program with two tracks. This was done to recognize the changing nature of products, communications, systems and services that increasingly act interdependently, mix hardware and software as well as products and information systems, and are designed by interdisciplinary teams. Replacing the previous program organized vertically into Product Design and Communication Design, is a new horizontal

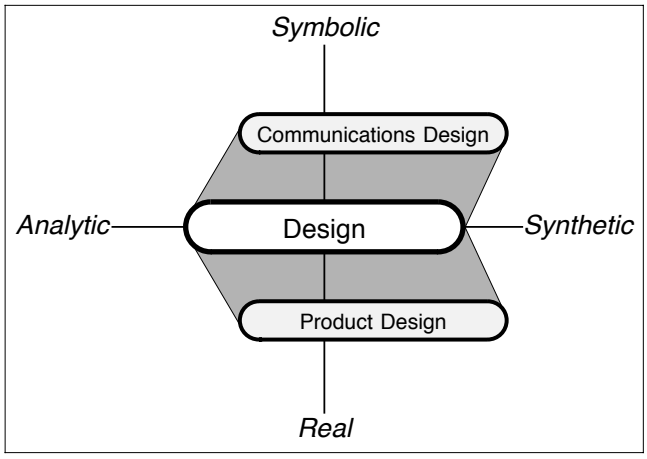


Figure 5. Merging and repositioning the Institute of Design's programs.

"track" division: Design Planning, concerned with issues of concept, process, program and planning; and Human-Centered Design, concerned with details, human factors, artifact and development. Both tracks deal with communications, products, services and systems.

In Figure 6, a new set of axes representing the degrees and tracks of the new program is matched to the map of disciplines. Matching the Analytic/Synthetic axis is an axis for the degrees: research degrees for inquiry, a professional degree for application. Matching the Symbolic/Real axis is the axis for tracks: Design Planning concerned with the concept-building aspects of design, Human-Centered Design concerned with the specifics of form and function.

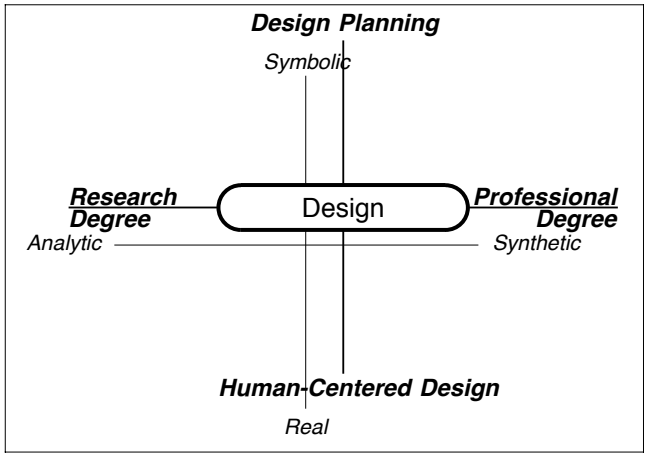


Figure 6. Matching a design program to the Map of Disciplines.

Extending the general model for knowledge using and knowledge building to the new axis system produces a four-lobed model (Figure 7). The four quadrants of the map articulate the purposes of design inquiry and application clearly for the two-track program. *Design Planning Research* students investigate and develop theory, methods and processes for planning and concept formation. *Human-Centered Research* students investigate and develop theory, methods and process for the detailed design of systems and services and their incorporated products and communications. *Design Planning Professional* students apply the tools of design planning to the creation of design plans for institutions and industry. *Human-Centered Design Professional* students apply the tools of human-centered design to problems of systems and services with their associated products and communications.

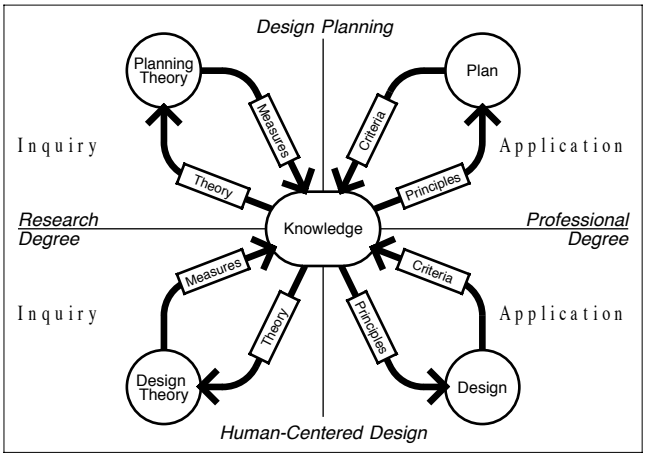


Figure 7. Graduate study at the Institute of Design.

DESIGN RESEARCH

What light does all of this shed on the subject of design research? For a beginning, there are several general insights.

Some General Insights

First, research should not be thought of as being limited in form, in particular, to the classical forms of scholarly and scientific research. Those forms of research, as processes of knowledge using and building in the service of inquiry, *are* practiced by nearly all disciplines, but to greater or lesser extents. Knowledge using and building for the purposes of application is an equally productive process, adding to a discipline's knowledge base through the contribution of worked examples. A corollary lesson from this reflection is that balance may be useful.

Second, the processes of knowledge using and building are fundamentally the same for inquiry and application. The differences are more in the purpose of the activity. In both cases what is

known is used to generate something new that will provide answers to questions inspired by a felt need. In the case of inquiry, the need is for deeper understanding of the subjects of a discipline; in the case of application, the need is for artifacts and institutions that employ the knowledge of the discipline more successfully.

Third, determinations of value must be understood to derive from the value system underlying a discipline. The kinds of questions framed by one discipline are not necessarily those of another. It is counterproductive, misleading and a mistake, for example, to attempt to determine "rightness" or "truthfulness" within a discipline if these are not the relevant kinds of questions to ask.

Fourth, a position far to the left or right on the Map of Disciplines opens special opportunities for kinds of research appropriate to the other side. Disciplines skewed to the analytic side probably have unexplored opportunities for knowledge building through applications. Disciplines on the synthetic side should look to areas of inquiry—frequently the tools of the discipline (theory, methods, process) are worthy subjects for research.

Fifth, within the processes of framing questions and constructing answers or decisions lies the heart of good research and, ultimately, the basis for its quality. Questions sharply honed against the context of a discipline's value system require answers similarly crafted and decisions equally well constructed. Creativity, whether discovery or invention, is inspired by good questions.

Recommendations for Design

The design disciplines are on the synthetic side of the Map of Disciplines, far enough to the right that their claims to accomplishments in matters of inquiry are not extensive. This suggests a movement correction to the left for balance. Several other recommendations can be made; those following are primarily for design education, but a discipline includes practitioners, educators, researchers and other associates with specialized responsibilities, so there are implications for many, including those responsible for collecting and disseminating design knowledge.

• Distinguish between research and professional advanced education. Graduate studies should be formalized to recognize the difference between studies to achieve mastery of the latest and most sophisticated design theory, methods and process (application), and studies to create new design theory, methods and process (inquiry). Degree titles can recognize these distinctions.

• Institute more structured programs of advanced study. Design has reached a level of maturity at which graduate courses can be taught with real information content. The master/apprentice model of an advanced degree course requiring only a longer, more thorough project is no longer adequate. Masters and doctoral programs with taught-course components are feasible and necessary.

• Define areas of design inquiry and application for which research is desired and establish funded centers and programs to accomplish the research. Design research has major potential value in a number of content areas—transportation, health care, information access, learning, work, urban systems, and design processes—to name just a few.

• Differentiate areas of design specialty and concentrate resources. Schools with specialized research programs can assemble equipment, financial and human resources synergistically to do better work than can be done with the same resources spread among many.

• Seek out faculty with research experience from disciplines related to design. To prime the pump, faculty members from other fields who are sympathetic to the goals of design can bring general research attitudes, procedures and rigor to the discipline. A few such interdisciplinary members will not dilute a design program, and their fresh ideas may well lead to useful evolutions in design research.

• Initiate studies of the philosophy of design. Just as studies of the philosophy of science, history, religion, etc. seek to understand the underpinning values, structures and processes within these systems of knowledge building and using, there need to be studies of the nature of design. The design disciplines need thoughtful study of how design proposals and works are produced and evaluated. Measures and criteria as well as procedures for use and judgment should have the same attention given to scientific method. What is the analogous *design method?*

• Extend the means for communicating design knowledge. Most analytically oriented disciplines have extensive infrastructures of confer-

ences, symposia, journals, text book publishing and other communication systems that attract, collect and distribute developing knowledge. These also act as recognition systems and create incentives for young faculty members to produce work of value.

• Inculcate knowledge-using more effectively in the question-asking phases of design applications. Design projects that have better thought-out beginnings will have better thought-out endings and, therefore, will be better candidates for building the experiential knowledge base.

CONCLUSIONS

Stepping away from the term *research* allows it to be seen more clearly. Asking instead how knowledge is built, widens the focus. With a broader view, it is possible to see how activities, seemingly opposed, actually work together to support the growth of knowledge.

A knowledge-using/knowledge-building model resolves the "who does research?" debate. Knowledge building is done in different ways, all of which contribute. In recognition of this, the Institute of Design has tailored its graduate programs to research and professional degrees (inquiry and application dimensions) paired with tracks for design planning and human-centered design (symbolic and real dimensions). Knowledge using and building are fundamental to the tracks in both programs.

The interest now being shown in design research is timely. Whether its inspiration is defensive (justifying educational budgets), competitive (contributing to an educational or industrial advantage), or simply idealistic (bringing the discipline to maturity), the impact will be the same. The health of our discipline will be well served by this needed attention to its foundations.