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Epistemology, Technology and Organization: the affects of change in architectural design

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Abstract
This paper investigates a number of changes occurring in the way we think about and produce design for the built environment. There are three major factors affecting change that will be examined: epistemology and the type of knowledge; technology and the method or process used; and organization in the division of labor. The interrelationship of each of these produces a complex matrix. This paper develops a theoretical model to map and measure these changes. It is important for educators because it provides a point of reference for preparing students and an understanding of the operational level at which academia and industry work. The goal of the paper is to present this initial idea and to obtain comment for future development.

Introduction

For the first time in history the technology exists to automate certain kinds of complicated cognitive design processes. Just as the Industrial Revolution freed man physically from many labor-intensive processes, the Computer and Information Technology (CIT) Revolution is freeing him or her cognitively from many tedious calculation and design tasks. No longer will young architectural interns be designing gang toilet plans, hip roof plans or basic wall sections nor will engineering interns be drawing steel framing plans or detailed shop drawings; it can all be designed by computer, the process is now automated! What will be left for the designer will be the design philosophy, the ideal value judgements and critical review of the automated design product itself. This is going to have a profound effect on the way we design, how we define it, produce it and teach it.

These technological changes are going to lead to a philosophical separation between academia and industry because certain cognitive processes will be completely automated by technology, thus rendering specific types of knowledge obsolete. In the same token, certain types of knowledge used as building blocks for learning can only be gained by using obsolete technology. In addition, the technology is fostering further division and compartmentalization of work in industry whereas academia prefers a more individual and holistic approach. Herein lies the problem, industry is moving toward one set of operational platforms in design that academia cannot use under its current thinking for pedagogical reasons.

In the past neither the operational or motivational differences between academia and industry produced real conflict. Each had their own domain, one theory and the other practice, that together produced a rich symbiotic relationship. Both used very similar operational platforms in terms of epistemology, technology and organization. Design was typically done by hand from start to completion by one or two individuals and learned under the tutelage of a master. In this respect, the entire design process for both had not advanced much beyond the craft level.

This paper will examine the underlying operational tendencies between academia and industry in three important areas: epistemology, technology, and organization. A three-dimensional model will be developed to map and show this operational divergence. New design typologies will be defined to distinguish between design that can be automated and design that cannot. In this process, conclusions will be made and recommendations given on how we should think about and teach design.

Background

Historical overview

These proposed changes are really part of a larger evolutionary process that needs to be set in historical context. The origin of doing, or learning to do, starts with the medieval craft system. The act of doing in this system was by hand using simple tools where the same person did every step in the process. Master craftsman passed down the knowledge of doing, from generation to generation, to apprentices. This represented the entire epistemological, technological and organizational structure and the starting point from which this argument is built upon.

The Enlightenment and the Industrial Revolution are the two most important human developments that define modernism from the medieval craft system.[1] The Enlightenment brought us the power of thought, outside the realm of a non-secular model, to explain the physical and social world. Knowledge from the singular act of doing was abstracted to form empirical and theoretical knowledge that explained and predicted phenomena without ever actually doing. From this we construct a simple epistemological structure for types of knowledge.

The Industrial Revolution brought a new technology that freed us from the manual labor of doing by hand and reorganized us in a way that promoted specialization in a particular operational act. In this sense, a worker could produce a complex product without ever actually touching it during most or all of the automated or mechanized process.[2] From here we develop various degrees of technological assistance and automation as a method or process of doing. We also begin to organize work in specialized categories thus creating divisions of labor.

The transformation from an industrial to a post-industrial society is marked by the replacement of manufacturing economy to a service society of managers, professionals and technical workers.[3] The use of raw material and practical knowledge as the mode of production is replaced with information and the use of theoretical knowledge. Knowledge is now a tool for productive power in a society of producers and consumers and an instrument of power itself.[4,5] Theoretically, this is important because it sets up the logical progression of automating cognitive processes instead of mechanical ones where information and knowledge is now the key raw material in a service economy. One can only wonder if this kind of technological automation will fully parallel the Industrial Revolution that led workers feel a of loss of control resulting in anomie, alienation and class conflict that Durkheim, Marx and Weber described a century earlier.[6,7,8]

Design Typology

The use of technology is driving fundamental change in the design process and is creating the need for a design typology based on the level of automation. This typology is organized along an axis where at one end design can be completely automated and at the other it cannot (*see Figure 1*). Design that can be completely automated is termed an applied science and defined as a process that is linear and causal with a fixed philosophical base that produces a measurable and repeatable outcome.[9] Both design acts create something new.[10] An example would be the structural steel design and detailing process or the design of a hip roof plan; both highly automated processes. Design that cannot be automated is termed a creative art and is based on an *ideal* type theoretical model with multiple variables where the outcome may seem arbitrary.[11] The designer makes a series of seemingly subjective open ended value judgements that result in the premise for the design.

Complete Automation/ Applied Science	**No Automation/ Creative Art**
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Linear process model	Ideal process model
Right or wrong solution	Good, better or best solution
Analysis based	Human value judgement
Predictable	Unpredictable

Figure 1

Axial Definitions

There are three major factors affecting change in design. Each will be defined in axial terms: epistemology and the type of knowledge; technology and the method or process used; and organization in the division of labor. These three axial definitions themselves are admittedly oversimplified and generalized but together will form the basis for developing a three dimensional model for examining the philosophical separation between academia and industry.[12]

Epistemology & Type of Knowledge

Types of knowledge here are defined as the developmental stages or activities that lead from a basic literacy to a comprehensive theoretical knowledge of doing. There are four categories of knowledge along this axis: literacy, craft, empirical and theory (*see Figure 2*).[13] Literacy is the knowledge to identify components without actually knowing how to design it. Craft knowledge is the knowing that comes from actual hands-on doing of design. Empirical knowledge is a compiled understanding of design codified into a rule-of-thumb, table, chart or regulatory standard that predicts simple behavior but without the ability to explain why. An example would be a floor span verses load chart to size a joist. Both craft and empirical knowledge are sometimes referred to as practical knowledge. Theory knowledge is the explanation of phenomena using a commonly agreed upon scientific methodology that is developed through a rigorous set of rules by a discipline of observation, identification, description, experimental investigation, to formulate a theoretical explanation of phenomena.[14] The relationship between a beam load, shear, moment and deflection diagram is a clear example of a quantitative engineering theory that predicts the behavior between them. A qualitative architectural theory is more difficult to illustrate because it often tries to define and explain socio-aesthetic and cultural phenomena.[15]

Figure 2

Technology & Method or Process

Technology is a tool that physically or mentally frees an individual from the act of doing, in part or all, thus changing or transforming the original method or process of doing.[16] This change or transformation from technology is defined as four categories along a *circulating* linear axis: observer, manual, assisted and automated (*see Figure 3*). Observer is the act of watching a method or process without doing. Manual is the actual doing by hand with simple tools of design. Assisted is a technology that somehow adds physical or cognitive, power to a method or process of design. An example would be a hand held calculator, a basic functioning AutoCAD program, and any power assisted tool. Automation is where the design process or method is entirely done by technology. An automation method or process also reduces one to an observer. A clear example of this entire technological progression would be the production of structural steel shop drawings, known as detailing. The observer in this example would be an apprentice watching shop drawing being done but can't do it by him or herself. The manual act of doing shop drawings would be drawing them by hand with a pencil. The assisted stage of doing with technology would be drawing by AutoCAD with many copy and paste features and using a calculator for many mathematical functions. The completely automated process would be where information from the steel framing plan is entered into a computer with design parameters and the computer completely draws all of the beams and columns without human intervention or need for any calculation. Both an apprentice and master detailer in the automated process are now observers where the difference between the two is epistemological. The automated process changes the master's task from one of doing design to one of doing analysis.

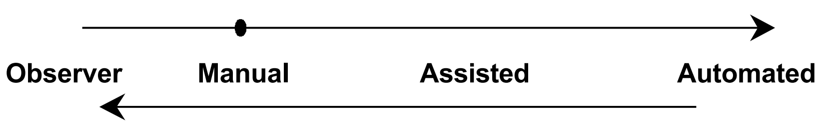

Figure 3

Organization & Division of Labor

Organization here refers to the technical division of labor involved in the production process and not social division.[17] The types of division along this axis range from an individual doing the entire process to an individual doing a small and highly compartmentalized part of a complicated process. There are three categories of division along this axis: individual, team and compartment (*see Figure 4*). The team is defined as individuals working together who only do a small part and don't see the entire design process. The compartment is defined as individuals who perform highly specialized task in design and do not usually see or do other individual functions. An outcome of the technological mechanization during the Industrial Revolution was the rapid division of labor resulting in new operational acts.

Figure 4

Three Dimensional Model

The epistemological, technological and organizational axis can now be combined to form a three-dimensional model shown below (*see Figure 5*). The model also plots the operational positions of academia and industry, with a detailed explanation to follow. This model is presented as an idea and is designed to be accurate, not precise in terms of position. Its use is to understand the interrelationship of these three factors between academia and industry that is causing a widening operational difference that will lead to a fundamental split.

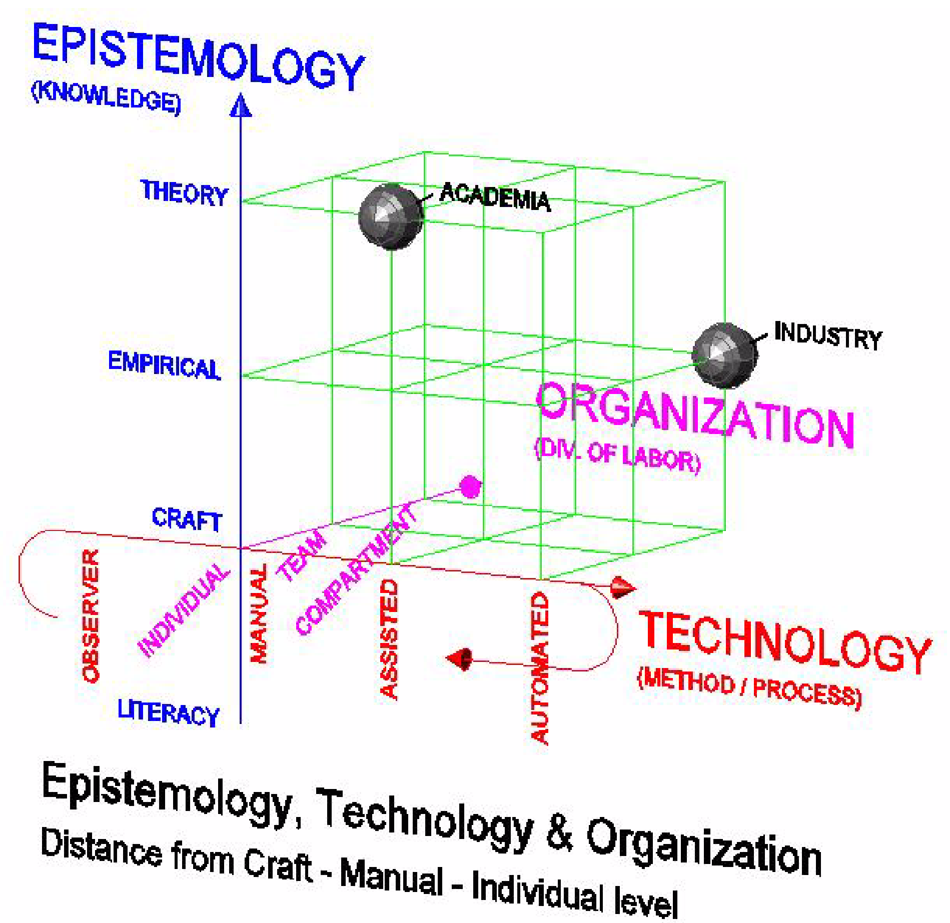

Figure 5

Academia Plotted

The position at which academia operates pedagogically on the model has been plotted at the following levels: epistemological: theory; technological: assisted; organizational: individual. The major factor that drives these positions is related to the central role that knowledge plays both culturally and institutionally in its production and the education of students.[18] In this case the epistemological axis will always be dominant over the technological and organizational axis.

Epistemologically
Academia is primarily interested in providing a theoretical explanation as to why a phenomenon occurs. This emphasis is evident in the kinds of knowledge it produces and in the way it presents it in educating students; understanding why we do something is more important than simply doing it. Both craft and empirical knowledge provide an answer but without an explanation.

Technologically
By default, academia operates technologically at the assisted level because the automated level reduces the student to observer and the craft level has a negative reputational impact for both marketing new students and providing its graduates jobs. McCleary also points out that technology creates an opaque, verses transparent, filter in the process of doing, and thus effects learning.[19] In this sense, the amount of technological assistance within this level is always going to be skewed toward understanding why and assessment and not toward efficient industry production.

Organizationally
Academia operates primarily at the individual level for pedagogical reasons related to student assessment. A compartmentalized approach to design also does not allow students to see or understand the entire process. The academic institution itself obviously operates in a highly compartmentalized manner. The issue here is on how we organize students to do design in a classroom studio verses how industry does design. In this sense, design remains primarily a singular and indivisible act.

Industry Plotted
The position at which industry operates on the model has been plotted at the following levels: epistemological: empirical; technological: automated; organizational: compartment. The major factor that drives these positions is related to the central role that economics plays in terms of cost, profit and risk. In this sense the technological and organizational axis will always be dominant over the epistemological axis because the production of design itself, using practical knowledge, is more important than the production of theoretical knowledge or providing an explanation of why.

Epistemologically
Industry operates at the empirical level because it is most concerned with solving the problem quickly, consistently and without risk and not with explaining or justifying it theoretically. Reducing the problem to a simple chart, basing decisions on industry standards and codes or starting with a proven building prototype meets these criteria. Operating primarily at either the theory or craft level is inefficient in terms of time spent problem solving and allows for unnecessary risk due to error or complexity.

Technologically
Industry always seeks to automate any method or process because it reduces labor cost in a

competitive market place and reduces risk through proven standardized repetition.

Organizationally
Industry seeks to divide work tasks into specialized compartments because of the efficiency and reduced risk of error in repetitive problem solving. Professional licensure and shared surety provide additional rationale for specialization. This explains why successful design firms develop highly specialized practices in terms of building systems or in basic building typology and divide operational tasks within the firm. The end result is higher fees, increased efficiency and reduced risk through repetition.

Model Inference
It is clear that the model in *Figure 5* shows a widening separation between academia and industry. The arguments locating each position on the model are based philosophically on a pragmatic approach to cultural and institutional goals. The possibility of academia and industry operating on different or obsolete epistemological or technological platforms in relation to one another seems apparent. A new way of thinking needs to be found to avoid a fundamental fracture.

Discussion
Romantic Tendencies
There is a romantic tendency to return to the operational origin of actually doing, or developing knowledge of, an entire design process by hand, by oneself. This can be seen as either a reaction against modernism, in terms of human control of the process, or a romantic ideal, architect as artist or master craftsman, for doing design. Arts & Crafts Movement of the late nineteenth and early twentieth centuries is in part a reaction to the loss of human control in an automated manufacturing and design process. The worker was reduced to observer that created monotony leading to feelings of alienation and anomie.

The romantic ideal of architect as artist or master craftsman is based on the operational mode of nearly all of the great architects of the modern period. As artists they professed working in a solitary state that expressed some deeply personal vision. Frank Lloyd Wright's design of Falling Water, arguably one of the greatest buildings of the twentieth century, is an example that idealizes this process in architecture. Wright drew the entire building in a single sitting by hand in essentially a solitary state, with a few apprentices quietly looking on, expressing a deeply personal vision. The work of Michael Graves as painter, architect and now designer of pop-culture artifacts is both a post-modern example and one of individual designer name branding.

We will see evidence of this tendency to return to a romantic past by criticism from industry in that the students cannot either think about or produce certain aspects of design; a correct diagnosis. Industry advisory boards will advocate a return to pencil and paper basics; an incorrect prescription.[20] The advisory argument against academia using an automated design process in the curriculum will only widen the philosophical and operational separation.

Legitimate Domains
Academia and industry have legitimate epistemological, technological and organizational domains that define them. In the past, this has produced a symbiotic relationship that has benefited both.

The epistemological differences between theory and practice were minimized because they shared a common operational platform in that both used a similar method or process of doing, a relatively simple division of labor and a tutelage system of learning. The problem now is that certain kinds of knowledge are going to be rendered obsolete because the technology exists to automate them. In the reverse, obsolete technology may be used to try to construct certain kinds of knowledge. The prospect of creating two kinds of platforms with two types of knowledge where each is obsolete in the other's domain remains a daunting prospect. In short, the integrity of each domain cannot be compromised and the use of separate platforms by both is problematic.

Conclusion

Toward A Design Typology

It should be clear that advances in technology are creating a fundamentally new operational act in design. This new act cannot be resolved in the existing epistemological and technological structure. The key here is that when the original act of doing is so fundamentally changed by technology that an entirely new act is created, then a division of labor occurs. The final conclusion of the paper is that a new division of labor is being created along the organizational axis defined by the design typologies as indicated in *Figure 1*.

Design is now a divided process with typological definition that ranges from an applied science that can be fully automated to a truly creative art that cannot. Automated design becomes design analysis in terms of a human operational act. Design analysis is not design creation, because it represents a different cognitive and operational act, although it is an integral part of the whole design process.[21] Design analysis or post-design is then analogous to the process of analyzing the context in pre-design.[22]

Once this new typological distinction is made, as a separate operational act within design, the anticipated divergence now becomes a convergence. Academia does not try to teach the type of design that can be automated, rather it teaches design analysis for that process. It then can use industry's automated technological platform and obviously its own type of knowledge in the design analysis process. Industry, on the other hand, is using a technology that automates mainly empirical knowledge. Empirical knowledge is the knowledge type that becomes primarily obsolete in industry through automation; the same type of knowledge that is primarily not used in academia. The result is that academia and industry will move closer epistemologically, technologically and organizationally.

What is the forecast for industry on these changes? Fewer people will be doing what we traditionally call design, more people will be doing analysis and the total number of professional in the entire process will be less. This should not be unexpected since it follows similar trends once technology is integrated into any process and the fallout should benefit the profession. It will also shift the dividing line between the role of architect, engineer and technician but that discussion will be left for a future paper.

Appendix

Design Typology Classification System[23]

A comparative test for developing a systematic classification of types that have characteristics or variables in common is presented in TABLE 1: Comparison of Computer Automation verses Human Value Judgement. A particular design act can now be tested in one or more of the following categories: Theoretical/Philosophical Operating Model; Mode of Production; Design Solution. From this, the design act can then be typed as a process of creation, analysis or a combination of both resulting in a hybrid process of creation and analysis. In the future, this typology will be developed to include refined combinations of operational acts.

TABLE 1: Comparison of Computer Automation verses Human Value Judgement

Computer Automation – Design Analysis	**Human Value Judgement – Design Creation**
Theoretical/Philosophical Operating Model • Applied science	• Interpretive art
• Causal model	• Ideal model (as defined by Max Weber)
• Linear decisions	• Multidirectional decisions
• Solves a common problem	• Tells an individual story
• Strictly rational	• Can be irrational
• Modernist approach	• Post-Modernist approach
Mode of Production • Standardized assemblies	• Highly varied assemblies
• Universal application	• Particular application
• Modular system	• Non-modular system
• Mass produced components	• One-of-a-kind prototype
Design Solution • Predictable solution	• Unpredictable solution
• Low creativity	• High creativity
• Scientific reason and process	• Literary reason and process
• Hard logic (cost, function, need)	• Soft logic (cultural, aesthetic, want)
• Right and wrong solution	• Good, better and best solution
• Analysis based defense	• Verbal argument defense
• Easy to measure	• Difficult to measure
• Apolitical	• Political

Bibliography / Endnotes

[1] Kenneth Frampton, Modern Architectural: A Critical History (New York: Oxford Univ. Press, 1980). Frampton points to these two events as a watershed for Modernism.
[2] Siegfried Giedion, Mechanization Takes Command: a contribution to anonymous history (New York: W.W. Norton & Co., (1948) 1975)
[3] Daniel Bell, The Coming of Post-Industrial Society (New York: Basic Books, 1973).
[4] Jean-Francios Lyotard, The Postmodern Condition: A Report on Knowledge (Minneapolis: Univ. of Minnesota, 1984).
[5] Michel Foucault, Knowledge/Power: Selected Interviews and Other Writings 1972-1977, ed. C. Gordon. (New York: Random House, 1976).
[6] Emile Durkheim, The Division of Labor in Society (New York: Free Press, (1893) 1984).
[7] Karl Marx, "Economic and Philosophical Manuscripts," In Karl Marx Selected Writings, (Paris) ed. David McLellan (New York: Oxford University Press (1844) 1977).
[8] Max Weber, Economy and Society, trans. and ed. G. Roth and C. Wittich (Berkley: University of California Press (1921-2) 1978).
[9] Donald Schon, "Toward a Marriage of Artistry and Applied Science in the Architectural Design Studio," in the

Journal of Architectural Education 41, no 4 (Summer 1988). This article provides a good list of applied science design activities that center on engineering and economics. He argues for a convergence of artistry and applied science while I am arguing that just the opposite will occur due to technological automation.
[10] The definition of what design *is* is based on a broad understanding that it creates something new and occurs at all levels. Some may define design narrowly as only the first move in an open-ended process and all other decisions thereafter are not creative.
[11] The definition of an ideal type model is borrowed from Max Weber's ideal value reference model to explain relationships in sociology. It is not based on a causal or linear analysis; rather these are ideal extremes that explain phenomena that require value judgements.
[12] It is important to note that in a short paper highly reductive definitions and arguments are used and are not intended to represent entire bodies of knowledge or to engage in intra-discipline debate.
[13] Peter McCleary, "Some Characteristics of a New Concept of Technology" in the Journal of Architectural Education 42, no 1 (Fall 1988). This article helped to develop and refine aspects of this axis.
[14] Based loosely on the definition of science in the American Heritage® Dictionary of the English Language, Third Edition.
[15] Christopher Alexander, "Goodness of Fit," Notes on the Synthesis of Form (Cambridge: Harvard Univ. Press 1964). Alexander presents a theory where the design form is based on fitting the cultural and physical context; something that he argues cannot be easily seen, defined or quantified.
[16] Giedion, ibid. This book provides the theoretical premise for technological transformation of a process. The parallels between mechanization, during the Industrial Revolution, to free one physically from many tedious labor tasks and the current computer information technology to free one mentally should be evident.
[17] The effects of the division of labor resulting in social division is extremely complex and one of the major focuses of social theory since the inception of sociology as a discipline.
[18] Lyotard, ibid. Lyotard states the importance of Universities as the dominant producers of theoretical knowledge in a post-modern society.
[19] McCleary, ibid.
[20] External industry advisors may remember back to the good old days when they were in college and advocate for that method or process of learning design and may be correlated by generation.
[21] Criteria for a design typology classification system was developed in parallel with this article and published in a separate paper. It is included in the appendix under Design Typology Classification System as supplemental information only.
[22] In fact, pre-design is recognized as a separate operational act and is one of several divisions that are tested separately on the national Architectural Record Exam.
[23] Joseph A. Betz, "Automation Takes Command: toward a design typology," Proceedings of American Society for Engineering Education (ASEE) Spring Regional Conference, at Kean University, April 2003. This paper fully develops the process by which this chart is constructed. It includes a historical progression of automation software, parallels with other technologies, setting of the categories, etc.

Biography

Joseph A. Betz is an Associate Professor of Architecture at the State University of New York at Farmingdale and a practicing Architect. He received his undergraduate and professional degrees in architecture from Rensselaer Polytechnic Institute and his post-professional degree in architecture from Columbia University. He is a recipient of the SUNY Chancellor's Award for Excellence in Teaching.