Acceptance Barriers
-- Why are Design Methods Not Accepted

W. Ernst Eder
Royal Military College of Canada

Abstract

Industry and academe has not accepted newer design methods (e.g. Design Science), and does not know about them. The methods that industry accepts (e.g. TQM, QFD, Taguchi, and many more) are claimed as "industry best practice", and industry wants academe to accept these methods as the height of knowledge. An explanation for this delay in accepting "foreign" results (in both directions) is needed. The circumstances are very complex and interacting.

Design Science is an ordered, categorized and coordinated set of knowledge about designing (including knowledge about designers) and the objects being designed, a theory. For any use of methods based on Design Science, or any other methods, they must be adapted to problem and situation, to different kinds of product, and the peculiarities of the enterprise.

Engineering designers develop their own methods, usually from explanations and practice. Only when an engineering designer meets a novel problem outside his/her immediate experience are any more formal procedures and methods needed. Such methods must usually be known in advance of the need to use them. There is always a general resistance to change from previous familiar ways.

It is necessary for future engineering designers to learn methodology during their engineering education. German investigations have demonstrated the beneficial results of teaching formal design methodology.

1. Introduction

Designing and design theories, methodologies and methods have been under intensive investigation since about 1960 (compare chapter 3 in [1]). In these investigations, several distinct trends can be found.

One, the artistic trend, claims that designing needs creativity (and only creativity?), that creativity is an inborn trait of particular humans, and that inspiration comes from an unknown source. In this way, the designer is unique, talented and privileged. Designing, in the extreme, cannot be taught or learned. Only a studio-type apprenticeship can reveal this design talent, and the teacher can only offer critical suggestions. Research about designing in this trend is almost non-existent, although a proportion of the current literature subscribes to this trend (e.g. [2]). Many experienced designers make this claim, and state categorically that all design methods are useless, are counter-productive, and even destroy creativity. These self-observations need

further consideration.
A second trend, the pragmatic, tries to suggest methodologies based on experience by which creativity and designing can be accomplished or assisted. The models offered are derived from design practice, and give advice about the steps and procedures that can help to accomplish (a) problem solving, and (b) progressive definition of the system to be designed. Even though many of these methodological models have been issued by academics, especially in European countries (e.g. [4,5]), they usually have a basis in the industrial experience of the authors. Some methods claim to enhance creativity in a direct way, e.g. brainstorming, Synectics, 3-6-5, etc. [6], but their effectiveness is not certain. Designers and researchers from the first trend claim that such methodologies are "too linear and rigid" and are therefore apparently useless. Nevertheless, they make designing to some extent learn able.

A third trend involves research into engineering design, denying the results of both the first and the second trend. It divides broadly into:

a. observational and protocol studies of designers in action;
b. quasi-mathematical treatments of parts of designing (e.g. [7], claiming to cover the whole of designing); and
c. computer algorithms for analysis and representation, including artificial intelligence applications.

Some of the individual methods have been found useful [8,9], some have been taken over from other applications. In addition, many "industry best practice" methods have been devised and introduced, especially with the backing of commercial interests.

A fourth trend has branched from the second, and has led to a more scientific view of designing. In this trend, the development during the design process of the system to be designed is followed step by step in a logical sequence, and in parallel the processes of designing are coordinated. The scheme culminates in Design Science [1] and its subsidiary publications (e.g. books [3,10--13] and many papers), and tries to include the results of all the other trends. Several papers in these conferences have referred to this theory (e.g. [14--18]), the scope of this paper does not allow any closer consideration.

2. Designing: Generalizations

Designing involves some flair, ability, intuition, creativity, spontaneity, serendipity, etc., but also judgment, reflection [19], feel, and experience of individual designers. It is necessarily heuristic [20], iterative, recursive, opportunistic, flexible, and idiosyncratic. Teamwork among designers and other participants plays a large role in the design process. All these human qualities are essential to designing, and the properties and inclinations of human designers need to be investigated. But as individual statements none of them captures the essence of designing. They seem to indicate that designing is exclusively a very personal and human matter. Nevertheless, designing is not isolated, it concerns an activity about an object -- a product -- performed by human designers with their tools (including computers) within an organization.

Rationalization and systematization, and even computerization and computer automation, for at least of parts of the design process, is possible and desirable. This is valid both in the (formal and informal) procedures of designing and in the progress of the system being designed. Full automation is usually not possible, it would deny the possibilities of innovation. Rationalization and systematization of designing depends partly on the individual class of products. Although many pragmatic and experience-based methods have been proposed and implemented, ideally a consistent and comprehensive theory about engineering design and the systems to be designed is required. Such a theory is delivered by Design Science [1].

The methods have been shown to help with conceptualizing solutions to design problems, by opening the solution spaces, and ensuring a full consideration of all factors. This should lead to optimization of the solution principles, and further improvements in the resulting engineering products. It should also lead to changes in engineering education.

3. Acceptance

Industry has in general not accepted newer design methods (e.g. Design Science), and does not know about them. The methods that industry accepts (e.g. TQM, QFD, Taguchi, and many more) are claimed as "industry best practice", and industry wants academe to accept these methods as the height of knowledge. These questions were raised by Sheldon [21] and Fulcher & Hills [22].

Even academe has generally not accepted the newer design methods. The emphasis in engineering education is still on the engineering sciences. Designing is wrongly seen as a poor relation with no scientific underpinning, and "competitions", "teamwork" and "creativity" are seen as adequate for design education. "Industry best practices" are of little concern, except when individual academic staff become familiar with a method and use it as an additional basis for their design teaching. Some methods are seen as useful when the comfort of academic life is under threat by financial difficulties.

An explanation for this delay in accepting "foreign" results (in both directions) is needed. The circumstances are very complex and interacting.

It is worth pointing out that even the individual "industry best practice" methods are each used in only a small fraction of industry. Some methods fit better with one organization than with another. Each method must be adapted to that organization, usually by members of that organization. Someone (a person) must have "ownership" of the method, and adapting and championing a method is a difficult task for which time is usually not available. Unless a visible success is attained in the first usage, the method is likely to fall into disuse almost immediately. Each such method (like each new product idea) needs a champion who shows enthusiasm and is willing to drive the process towards acceptance.

Champions can most easily be found when economically powerful bodies ask for action, either top-level executives, or selling organizations as with most of the "industry best practice" methods. Other players are not as powerful, their work tends to languish. Is this a reason to distrust the powerful coalitions, and the drive towards internet-based learning?

4. Aspects of learning

Any learning involves a change in the learner. In the early years of life, learning is relatively easy, but still proceeds as occasional and intermittent leaps forward, interspersed with periods of stagnation. Static periods are necessary to consolidate the newest learning, expand its scope, and fit it into the learner's mental structures. This periodic progress may be related to Kolb's learning cycle [23], and models of problem solving. At times, a mental re-structuring becomes necessary (compare Perry's model [24,25]), which causes at least some trauma, but also at times the phenomenon of serendipity, inspiration, intuition, the "aha" experience, when the restructuring has been successful. Any learning also includes some losses in previously learned aspects [26].

All learning includes facts, relationships, but importantly also methods. Facts and relationships (internalized object knowledge) is usually well explained and supported by theories, is more or less recallable, and can be examined by formal techniques. Methods are usually not explained, although there are exceptions [27]. Methods, whether learned formally or "by doing" (from experiencing), become internalized as stereotypes and masters (NOTE: stereotypes are not all bad, most are necessary for life). These stereotypes and masters are then processed in the sub-conscious mind when the occasion arises, and produce almost instantaneous (but mostly for that person conventional) responses -- labelled instinctive and intuitive. In this state, the person is not aware that he/she is using a specifiable method, and even denies using a method at all. This could explain the first (artistic) trend in design investigations and the claims of experienced designers.

5. Design Science

The usable methods and models have been brought into the framework of a comprehensive theory -- Design Science -- which coordinates designing and the progressive development of the future product with the theory.

The term Design Science is in general mis-understood, falsely interpreted as a meta-science of engineering (which, it is said, cannot possibly be generated), or as unordered conglomerate of all that is known about designing.

In the terminology of this paper, Design Science is an ordered, categorized and coordinated set of knowledge about designing (including knowledge about designers) and the objects being designed. As figure 1 shows, Design Science contains the theories (descriptive knowledge) of technical systems and of design processes, and prescriptive knowledge as advice about designing("know-how") and objects being designed ("know-what"). A vast array of related knowledge is clustered around Design Science, the interactions are many and varied.

For any use of Design Science, or any other methods (including the "industry best practices") the problem and product must be appropriate. The method must be adapted to problem and situation, adapted to different kinds of product, and the peculiarities of the enterprise [1,10,28]. Methods tend to be more useful for clarifying problems and for conceptualizing solution proposals, where active creativity may be essential. For embodying and elaborating, creativity is

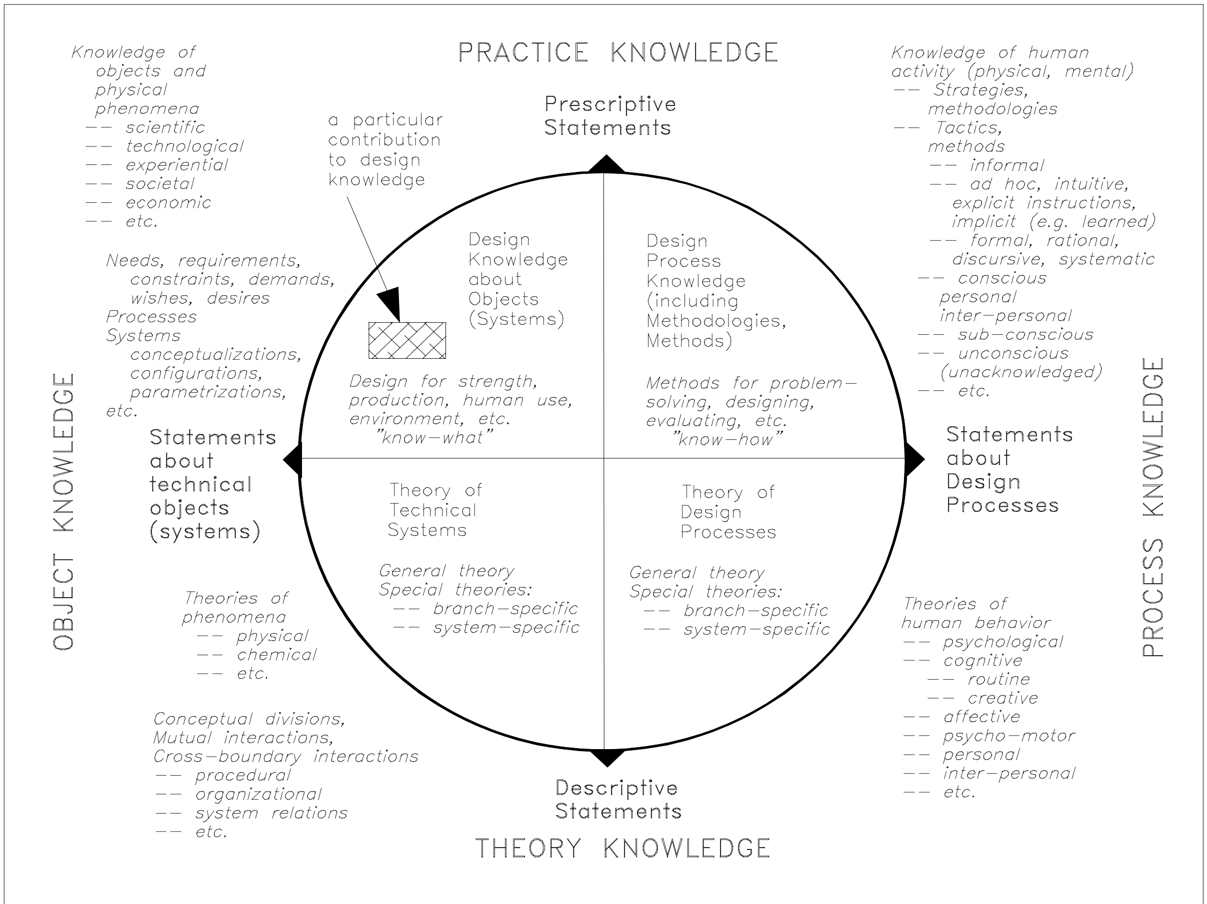

Figure 1 Categories of Engineering Design Knowledge

less essential, and more experience knowledge is required, although many innovations can be implemented at this level.

Most engineering designers work within a relatively narrow set of design problem (a product family), see [1,10,28]. Procedures and typical solutions (organ structures and parts of component structures) are well known, even if they are not spelled out in detail. Only when an engineering designer meets a novel problem outside his/her immediate experience are any more formal procedures and methods needed.

Such methods must usually be known in advance of the need to use them. Learning "on the job" is in any case difficult, unless it is fully supported by top-level management. There is then a pressure of needing a (quick) success, as well as the time pressure to obtain a solution. Usually companies and designers try to implement a complex method all at once, and commonly find that they do not succeed sufficiently well, get discouraged, and then reject all methods. It is far better to implement methods gradually, as successes are achieved, and experience grows.

A good understanding of the method and its underlying theory is important for theory-based methods. Then the procedure that is prescribed (or rather, recommended) for the method makes more sense, therefore producing less stress, and a better direction towards the goals.

Previously there was a need to define Design Science well enough to provide wide coverage and logic. Only now, with the publication of Design Science [1], has sufficient maturity been reached in the theory that we can be ready to try to re-interpret design methodology for engineering practice. This will still take a certain amount of time, although some parts of the insights are already accepted.

6. Industry Usage

As Kuhn [29,30] has pointed out, it takes one to two generations for a major new insight (a change in the disciplinary matrix, a paradigm shift) to be generally accepted. Why should Design Science be accepted any quicker? There is always a general resistance to change from previous familiar ways, especially if the expected leap is large [31,32]. Even in academe there is a resistance to accept good points from other schools of investigation.

Unfamiliar terminology, outside ones own experience, and use of familiar words in a different context make the transition even more difficult. Add to this the requirement in academe for novelty and originality in ones research and publications, and for peer review (sometimes slanted to accept only what fits into a particular peer group), and the difficulties are even greater.

7. Needs for Education

This points to the conclusion that it is necessary for future engineering designers to learn methodology during their engineering education. Then the methods are familiar enough to apply, even if there is resistance from a supervisor. German investigations have demonstrated the beneficial results of teaching formal design methodology [33,34,35,36]. These results have become available after 25 years of teaching methodologies, and some of the graduates (with early versions of these methodologies) advancing in industry as leading engineering designers.

8. Closure

Academe should lead the renewal of designing as a discipline, by introducing formal design methodologies, preferably based on Design Science. The results, in the form of better products, will not become visible for many years. Hopes of having design methodologies introduced into engineering practice are slender, their introduction depends on knowledge and power, both of which may not be available.

Bibliography

1. Hubka, V. and Eder, W.E. (1996) *Design Science: Introduction to the Needs, Scope and Organization of Engineering Design Knowledge* (London, Springer-Verlag)
2. Tuomaala, J., "Creative Engineering Design -- Summary of a Book", in [3], p. 23--33

3. Eder, W.E. (ed) (1996) *WDK 24 -- EDC -- Engineering Design and Creativity* -- Proceedings of Workshop EDC (Zürich, Heurista)
4. Pahl, G. and Beitz, W. (1977) *Konstruktionslehre* (1993 3 ed.) (Berlin/Heidelberg, Springer-Verlag); *and* (1995) *Engineering Design* (2 ed: Edited and translated by K.M. Wallace, L. Blessing and F. Bauert), (London, Springer-Verlag)
5. -- (1985) VDI Richtlinie 2221: Methodik zum Entwickeln und Konstruieren technischer Systeme und Produkte (Düsseldorf, VDI); *and* -- (1987) VDI Guideline 2221: Systematic Approach to the Design of Technical Systems and Products (Düsseldorf, VDI) (edited by K.M. Wallace)
6. Holt, K., "Brainstorming -- from Classics to Electronics", in [3], p. 113--118
7. Suh, N.P., *Principles of Design*, Oxford: University Press, 1989
8. Cross, N., *Engineering Design Methods* (2 ed: Strategies for Product Design), London: Wiley, 1994
9. Birmingham, R., Cleland, G., Driver, R., & Maffin, D., *Understanding Engineering Design*, London: Prentice-Hall, 1997
10. Hubka, V. and Eder, W.E. (1988) *Theory of Technical Systems* (Berlin/Heidelberg & New York, Springer-Verlag)
11. Hubka, V. (1976) *Theorie der Konstruktionsprozesse* (Theory of Design Processes) (Berlin, Springer-Verlag)
12. Hubka, V. and Eder, W.E. (1992) *Engineering Design* (Zürich, Heurista)
13. Hubka, V., Andreasen, M.M. and Eder, W.E. (1988) *Practical Studies in Systematic Design* (London, Butterworths)
14. W.E. Eder, Problem Solving is Necessary, but Not Sufficient, ASEE Annual Conference, Educational Research and Methods Division, Session 2330, Milwaukee, WI, 15-17 June 1997, Washington: ASEE (CD-ROM)
15. W. Ernst Eder, Methods Allocated to Design Stages, in Proc. ASEE Annual Conference, Design in Engineering Education Division, Session 2225, Washington, DC, 23-26 June 1996
16. W. Ernst Eder, Teaching About Methods -- Coordinating Theory-based Explanation with Practice, in Proc. ASEE Annual Conference, Educational Research and Methods Division, Session 3230, Washington, DC, 23-26 June 1996
17. W.E. Eder, Learning Design -- Advantages for Procedures, presented in Session 2525, ASEE Annual Conference, Design in Engineering Education Division, Anaheim, CA, 25-28 June 1995
18. W.E. Eder, Learning Design -- Advantages for Procedures, in Proc. 1995 Annual Conference, Washington, DC: ASEE, 1995, p. 1145-1148
19. Schön, D.A. (1983) *The Reflective Practitioner: How Professionals Think in Action* (New York, Basic Books)
20. Koen, B.V. (1985) *Definition of the Engineering Method* (Washington, D.C., ASEE)
21. Sheldon, D. (1997) "Does Industry Understand and Adopt Design Science and Tools," unpublished paper presented at ICED 97 Tampere, International Conference on Engineering Design, August 19-21,
22. Fulcher, A.J. & Hills, P. (1996) "Towards a Strategic Framework for Design Research," *Jnl. Eng. Design*, **7** No. 2, p. 183--194
23. Kolb, D.A., *Experiential Learning: Experience as the Source of Learning and Development*, Englewood Cliffs, NJ: Prentice-Hall, 1984
24. Perry, W.G., *Forms of Intellectual and Ethical Development in the College Years: A Scheme*, New York: Holt, Rinehart, 1970
25. Perry, W.G., Jr, "Cognitive and Ethical Growth: The Making of Meaning", in Chickering, A. & Assoc., *The Modern American College*, San Francisco: Jossey-Bass, 1981
26. Egan, K., *The Educated Mind -- How Cognitive Tools Shape Our Understanding*, Chicago: University Press, 1997
27. Woods, D.R., *Problem-based Learning*: How to Gain the Most from PBL, Waterdown, ON: D.R. Woods, 1994
28. Frost, R.B. (1994) "A Suggested Taxonomy for Engineering Design Problems," *Jnl. Eng. Design*, **5** No. 4, p. 399--410
29. Kuhn, T.S. (1970) *The Structure of Scientific Revolutions* (2 ed.) (Chicago, Univ. of Chicago Press)
30. Kuhn, T.S. (1977) *The Essential Tension: Selected Studies in Scientific Tradition and Change* (Chicago, Univ. of Chicago Press)
31. Müller, J. (1991) "Akzeptanzbarrieren als berechtigte und ernst zu nehmende Notwehr kreativer Konstrukteure -- nicht immer nur böser Wille, Denkträgheit oder alter Zopf" (Acceptance Barriers as Justified and Serious Defence Reaction of Creative Designers -- not always Ill Will, Thinking Inertia or Old Hat), in V. Hubka (ed), *WDK 20: Proc. of ICED 91* (Zürich, Heurista) p. 769-776; and "Acceptance Barriers as Justified and Serious Defence

Reaction of Creative Designers -- not always only Ill Will, Thinking Inertia or Old Hat," in [3] p. 79-84
32. Müller, J., "Akzeptanzprobleme in der Industrie, ihre Ursachen und Wege zu ihrer Überwindung" (Acceptability Problems in Industry, their Causes and Ways to Overcome them), in Pahl, G. (ed) (1994) *Psychologische und pädagogische Fragen beim methodischen Konstruieren* -- Ladenburger Diskurs (Köln: Verlag TÜV Rheinland) p. 247--266
33. Fricke, G., and Pahl, G. (1991) "Zusammenhang zwischen Personenbedingtem Vorgehen und Lösungsgüte" (Relationship between Personally Conditioned Procedure and Quality of Solution), in *WDK 20 -- Proc. International Conference on Engineering Design -- ICED 91 Zürich* (Zürich, Heurista) p. 331-341
34. Pahl, G. (1995) "Transfer Ability as Educational Goal," in *WDK 23 -- Proc. International Conference on Engineering Design -- ICED 95 Praha* (Zürich, Heurista) p. 247-252
35. Dörner, D., Ehrlenspiel, K., Eisentraut, R., & Günther, J. (1995) "Empirical Investigation of Representations in Conceptual and Embodiment Design," in *WDK 23 -- Proc. International Conference on Engineering Design -- ICED 95 Praha* (Zürich, Heurista) p. 631--637
36. Günther, J., & Ehrlenspiel, K. (1997) "How Do Designers from Practice Design?" in Frankenberger, E., Badke-Schaub, P., & Birkhofer, H. (eds), *Designers: The Key to Successful Product Development*, Berlin/Heidelberg: Springer-Verlag, p. 85--97

W. ERNST EDER

Educated in England and Austria, with ten years of industrial experience, his academic appointments cover the University College of Swansea (1961-67), The University of Calgary (1968-77), Loughborough University of Technology (1977-81) and the Royal Military College of Canada, Kingston, Ontario. Ernst Eder has attained an international reputation in systematic design, theory, methodology and teaching.