# Design Science Research: Grand Challenges, Design Research Thrusts, Convergent Research, and the Pervasiveness of Design

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Of all of the concepts, theories, and content that are considered to comprise academic and professional pursuits, such as engineering, no subject is more pervasive and, perhaps, enigmatic than design. Design represents the bridge between theory and reality. It is the process by which our ideas enter and influence society, and vice versa. "Designing" distinguishes many fields, and defines them as professions. Academically, this pervasiveness of design is manifested, at least in one form, as design science research.

Compared to the physical, life, and social sciences, design science research is in its relative infancy. As a recognized scholarly field of endeavour, its existence may be characterized in mere decades. Scholarly venues for academic discourse and publication in design are vibrant, mature and impactful, yet relatively short lived. Academic positions in design science research at the world's most distinguished institutions of higher education have only recently solidified and gained significant traction. International societies and organizations have likewise only recently been created, and are emerging at an amazing rate. This relative young and exciting existence of design science research begs the question: what is design science research today, and what might it be in the future?

Design science research represents the scientific study of design [Frischknecht , et al., 2009][1]. It includes a number of driving characteristics:

- Systematic study, identification, and recognition of underlying principles (such as [Altshuller, 1997[2]; Singh, et al., 2009[3]]);
- Guidelines for its execution and rigor, such as those espoused by Hevner, et al. [2004[4]] and Purao, et al. [2008[5]]: design as an artefact [service or system], problem relevance, design evaluation, research contributions, research rigor, design as a search process, and research communication;
- Application of the scientific method and related design research methods (DRM), including inductive and deductive research methodologies [Blessing and Chakrabarti, 2009][6];
- Study and advancement of design processes, theory, methods, and practice;
- Collaborations of multiple disciplines and multidisciplinary approaches to the creation, validation, and translation of science-based design knowledge.
- Partnership and interconnectedness with the humanities, arts, and social sciences (HASS) given design as a human endeavour, or at least to impact human existence and society.

While these characteristics help to define design science research, and while significant advancements and impacts have been realized, design science research, today, is rather disciplinary centric and dispersed. Particular disciplines, such as engineering, architecture, information science, graphic arts, and industrial design, perform design research in various

forms and with particular venues for archival publications of research findings. Cross-disciplinary initiatives are reported and published, but at a much lower rate than within the disciplines. Even with the recognized findings of disciplinary design science research, the conceptual network of design science research is sparsely connected, recognized, and cited between the disciplinary nodes. There are emerging linkages, but the network is nascent.

Development of this network for the future holds great promise. There exist multiple dimensions that will catalyse, enrich, and cultivate this network, and design science as a research field, including:

- *Grand Challenges:* There is value and merit to the ideal study of design, its processes, and principles. But the scientific study of design should not be performed in isolation, but in the context of technological advancements, services, industrial processes, and societal need. The pursuit of solutions to the world's Grand Challenges can provide no better forum for this context. Exemplar grand challenges include those published from the National Academy of Engineering [NAE, 2008][7]. A subset of these challenges might also include Sustainable Built Environment (architecture, urban planning, cities, and large scale systems such as water, transportation and energy), Design with the Developing World (participatory design, social advancement and emerging markets), and Smart Nation (or ICT enabled devices and systems for better living) [http://idc.sutd.edu.sg/facts/grand-challenges/].
- *Design Research Thrusts:* Design Research Thrusts define the areas of design research that are critically important to advance design science and ultimately affect design practice. The full-value chain of design, from identification of an opportunity through implementation and sustainable operation, define innumerable possibilities and thrusts that could be pursued. The continued development and evolution of these thrusts will greatly enable a design science research. Example thrusts include Experimental Design, Design Computation (including big data and data analytics), Visualisation and Prototyping, Fostering Creativity, Decision Making, and Global Collaboration ) [http://idc.sutd.edu.sg/facts/design-research-thrust/].
- *Interactions*: The pursuit of design science research through the interaction of grand challenges and design research thrusts can have profound effects. If many multidisciplinary design science projects include at least one grand challenge (or rich and meaning application or opportunity) and one design research thrust, interaction effects may lead to fascinating results as a feed-forward and feedback system. As research or practice is carried out in grand challenges, results will inform the need for improved design theories, principles, processes and methods. And as design research is carried out in design thrusts, the effect of designing solutions to grand challenges will be more pronounced [http://idc.sutd.edu.sg/facts/].
- *Convergent Research:* Design science research represents the balancing of traditional disciplinary research and contemporary convergent research, i.e., achieving higher levels of integrative research across disciplines. Such research is expressed in different forms: multidisciplinary, interdisciplinary, and trans-disciplinary [Gericke and Blessing, 2011][8]. Design science research community has the opportunity and necessity to explore, prototype, test, study, and practice the mechanisms of convergent research in new and exciting ways.
- *Big-D Design*: Design science research must take on a very broad view and understanding of design, noted here as "Big-D Design" [Magee, et al., 2012[9], 2013[10]; Wood, et al., 2012[11]]. "Big-D Design" includes all technologically-intensive design, from architectural design to product design, software design, service design, and

systems design. It is design through conception, development, prototyping, manufacturing, operation, maintenance, recycling, reuse, and overall sustainability – the full value chain. It includes an understanding and integration of the liberal arts, humanities, and social sciences. In short, Big-D encompasses the art and science of design; for more information about the university and its concepts, see references.

- *Epistemology Relationships of Design*: Advancement of design science research will be needed in the epistemological relationship of design science to natural science, social sciences, and engineering science. An aggressive attempt to clarify these relationships will have great value in setting an agenda for pursuing design science research [Magee, et al., 2013].
- *Pinnacle of Design*: Pinnacle design opportunities have the characteristics of being cross-disciplinary, "wicked" in nature [Buchanan, 1992][12], impactful on society (making a difference and making a splash), recognized and appreciated by one or more groups or communities, and requiring innovative solutions that have not existed previously. Design science research can benefit greatly through the pursuit of pinnacle design opportunities through the translation of design science knowledge to practice.
- *Pervasive Design Practice*: In the growing global interactions and flat world, responsiveness, flexibility, changing work force, and sustainability are becoming more pronounced. These factors lead to a natural need for design capabilities, skills, and mind set across all professions and organizations. Design science research will be affected by these factors and associated phenomena, and will need to be responsive to them. New knowledge, educational approaches, and partnerships will not be created just for designers or selected disciplines, but for all people.

Design science research today is exciting and impactful. This excitement and impact will continue and increase, but design science research in the future will be profound and expand across grand challenges, between emerging design research thrusts, through convergent research, across the full value –chain of design, throughout communities, organizations, and cities, and across national and cultural boundaries. Design science research will continue to build a cumulative research enterprise around design and upon a reliable base. It will favourably impact design practice by development of new methods, theories, guidelines, heuristics and principles that when applied directly lead to superior results for practicing designers, teams, communities and organizations. It will also favorably impact practice through results that point to superior education methods (Dym, et al. [2005][13]) that can involve better basic knowledge structure to support design and better exposure to methods and experiences that are effective in practice, business, and social enterprises.

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