A Methodology for Design Research:

Module 1: Introduction

Centre for Product Design and Manufacturing
Indian Institute of Science, Bangalore, India
Teaching Course, NPTEL 2013

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Resources used in this course

- **The course is based on the DRM framework developed by Amaresh Chakrabarti, author of this course, jointly with Lucienne Blessing and Ken Wallace. Where not specifically cited, the main reference material used is the following book (highlighted in red) and papers (in red):**
  - **Blessing, LTM, Chakrabarti, A. DRM A Design Research Methodology, Springer-Verlag, London, 2009**
  - Harivardhini, S., and Chakrabarti, A.: Expanding DRM Framework to Formulate Supreme Causal Models from Research Articles in the Area of Product Disassembly. Chakrabarti, A. (Ed.) ICoRD15: – Research into Design Across Boundaries Volume 1, Smart Innovation, Systems and Technologies Series Vol. 34, Springer-Verlag, India, ISBN 978-81-322-2232-3, pp 109-120, 2015
  - Chakrabarti, A. and Blessing, L.T.M. (Editors): An Anthology of Theories and Models of Design: Philosophy, Approaches and Empirical Explorations, Springer-Verlag, London, UK, ISBN: 9781447163374, 2014
  - Chakrabarti, A. Towards a Taxonomy of Design Research Areas, Herbert Birkhofer (Editor), The Future of Design Methodology, Springer, pp 249-260, ISBN 978 0 85729 614 6, 2011
  - Chakrabarti, A. A Course for Teaching DRM - A Methodology for Design Research, Special Issue on Design Pedagogy: Representations and Processes, Dan Frey, Bill Birmingham and Clive Dym (Eds.), AI EDAM Vol.24, No.3, 317-334, 2010
  - Chakrabarti, A. A Postgraduate Course on DRM – A Methodology for Design Research, in Proceedings of the Indo-US Workshop on Design Engineering, Chakrabarti and Subrahmanian (Eds.), Allied Publishing, Bangalore, 2008
  - Blessing, L.T.M., and Chakrabarti, A. DRM: A Design Research Methodology, in International Conference on The Science of Design - The Scientific Challenge for the 21st Century, INSA, Lyon, France, 15-16, 2002
  - Blessing, L.T.M., Chakrabarti A. and Wallace, K.M. An Overview of Design Studies in Relation to a Design Research Methodology, Designers: the Key to Successful Product Development, E. Frankenberger, P. Badke-Schaub and H. Birkhofer (Eds.), Springer-Verlag, 1998
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- Other reference materials used (where specifically cited but not given full reference):
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"What we observe is not nature itself, but nature exposed to our method of questioning."

Image Credit: http://commons.wikimedia.org/wiki/File:Bundesarchiv_Bild183-R57262,_Werner_Heisenberg.jpg

Werner Heisenberg

(Nobel Prize in Physics, 1932)

Course Outline

- Currently very few courses teach methodology for carrying out research into design.
- This course provides a broad overview of the generic concepts of design, design research and need for a design research methodology.
- It introduces DRM – a methodology for doing design research that is being used extensively as a framework for writing research proposals, planning research programmes, and carrying out design research.
- It then takes the student through each stage of the methodology:
  - clarifying research goals, criteria and questions
  - understanding design as a phenomenon
  - improving any of its facets in a systematic way
  - evaluating the improvements in a methodical manner.
- The course is designed particularly for students researching into design, to help
  - Develop a holistic understanding of the area of design research
  - Carry out design research effectively and efficiently.

Course Blocks

Block	Topic	Lecture
1.	Introduction to design and design research: What and Why; Major facets of design and design research, Current issues with design research and the need for a design research methodology	Modules 1-5
2.	Introduction to DRM - a design research methodology - its main components, and examples to explain the components, Types of design research	6-10
3.	Starting design research: Clarification of requirements: Identifying research topics, carrying out literature search, consolidating the topic into research questions and hypotheses, determining type of research to be persuaded and developing a research plan	11-17
4.	Types of descriptive study; Processes for carrying out descriptive studies for developing an understanding a facet of design and its influences; Introduction to associated descriptive study real-time and retrospective research methods for data collection such as protocol analysis, questionnaire surveys, interviews etc; Introduction to quantitative and qualitative data analysis methods	18-28
5.	Types of prescriptive study; Processes for developing design support and associated prescriptive study research methods	29-33
6.	Types of support evaluation; Processes for evaluating a design support, and associated Evaluation study research methods	34-37
7.	Types and structures of research documentation; Approaches and guidelines for documenting and reporting research process and outcomes	38-40
	TOTAL	40

Module 1:

Stories of Research from multiple domains, Introduction to design research, Outline of the course

Research Story 1

Image Credit: File:Pendule de Foucault.jpg
From Wikipedia, the free encyclopedia

“In Paris, a French scientist named Jean Bernard Léon Foucault suspended a 62-pound iron ball with steel wire, 220 feet long, from the dome of the Panthéon and set it in motion, rocking it back and forth. To chart the movement Foucault attached a marker extending from the ball so that it barely touched a circle of damp sand underneath. Normally what one would expect is for the pendulum to trace the same places over and over again. Yet to the astonishment of the crowd the pendulum appeared to shift positions leaving a slightly different trace with each swing. What was actually happening was that the floor of the Panthéon was rotating…

Source: http://www.newrealities.com/index.php/articles-on-new-sciences/item/163-top-ten-most-elegant-physics-experiments-of-all-time-adapted-by-alan-steinfeld

Research Story 1…

Image Credit: File:Pendule de Foucault.jpg
From Wikipedia, the free encyclopedia

…It takes 30 hours at the latitude of Paris for the pendulum to complete a full clockwise rotation. When Foucault's pendulum was used in the southern hemisphere it rotated counterclockwise. On the equator it doesn't revolve at all. Scientists have recently confirmed that the period of rotation at the South Pole is 24 hours to return to its originally traced line."

Source: http://www.newrealities.com/index.php/articles-on-new-sciences/item/163-top-ten-most-elegant-physics-experiments-of-all-time-adapted-by-alan-steinfeld

Validation: Theory-driven Prediction

- Theory used to generate new hypothesis: prediction
  - Theory: Earth rotates, therefore
  - Hypothesis: pendulum should appear to rotate
- Prediction is **falsifiable**
  - The Hypothesis has the possibility of being wrong
  - If pendulum does not appear to rotate (anywhere), earth does not rotate
- Prediction is found to be correct
- Considered an evidence of truth of the theory

Research Story 2

“As Darwin grew and studied several native orchid species, he realized that the intricate orchid shap-es were adaptations that allowed the flowers to attract insects that would then carry pollen to nearby flowers. Each insect was perfectly shaped and designed to pollinate a single type of orchid, much like the beaks of the Galapagos finches were shaped to fill a particular niche. Take the Star of Bethlehem orchid (*Angraecum sesquipedale*), which stores nectar at the bottom of a tube up to 12 inches (30 centimeters) long. **Darwin saw this design and predicted that a "matching" animal existed**. Sure enough, in 1903, scientists discovered that the hawk moth sported a long proboscis, or nose, uniquely suited to reach the bottom of the orchid's nectar tube…

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Image Credit: Life Pictures/ Mansell/Time Life Pictures/ Getty Images

Source: http://dsc.discovery.com/tv-shows/curiosity/topics/10-science-experiments.htm

Research Story 2…

…-Darwin used the data he collected about orchids and their insect pollinators to reinforce his theory of natural selection. He argued that cross-pollination produced orchids more fit to survive than orchids produced by self-pollination, a form of inbreeding that reduces genetic diversity and, ultimately, survivability of a species. And so three years after he first described natural selection in "On the Origin of Species," Darwin bolstered the modern framework of evolution with a few flower experiments."

Image Credit: Life Pictures/ Mansell/Time Life Pictures/ Getty Images

Source: http://dsc.discovery.com/tv-shows/curiosity/topics/10-science-experiments.htm

Validation: Theory-driven Prediction

- Theory used to generate new hypothesis: prediction
  - Theory: Species evolve to be fitter to survive, using various strategies
  - Theory: A strategy is symbiosis: Moths and orchids help evolve each other
  - Prediction: **For a given orchid, there must be a specific moth**
- Prediction is falsifiable
  - The Hypothesis has the possibility of being wrong
  - If no such moth exists, perhaps theories) are not true
- Prediction is found to be correct
- Considered an evidence of truth for the theory

Research Story 3

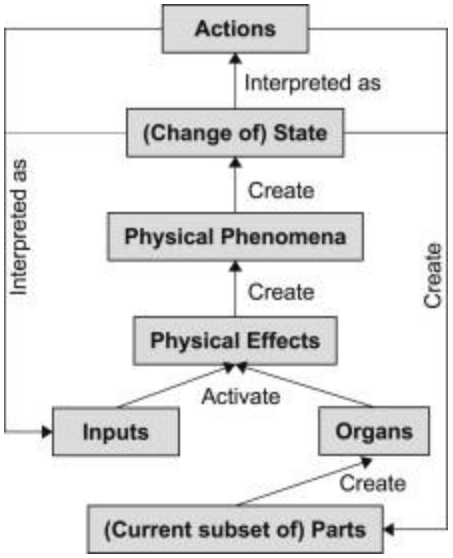

Image Credit: Chakrabarti et al., 2005

Nidamarthi et al. [1997] had found that requirements and solutions evolve together from general to specific. Similar claims were made by Dorst and Cross [2001].

-SAPPhIRE model is a model of system causality. SAPPhIRE stands for State change, Action, Part, Phenomena, Input, oRgan, and Effects. It claims that parts have organs, which together with inputs activate effects, which activate phenomena. This leads to state change of the parts, which is interpreted as action. State change may lead to change in parts leading to change in oprgans, either of which may act as new organs or inputs, for activation of new effects and phenomena [Chakrabarti et al., 2005]…

Nidamarthi, S., Chakrabarti, A., and Bligh, T.P. The Significance of Co-evolving Requirements and Solutions in the Design Process, Proc. Intl. Conference in Engineering Design, Tampere, Vol 1, pp-227-230, 1997

Dorst, K. and Cross, N. Creativity in the design process: co-evolution of problem–solution, Design Studies, 22(5), pp. 425–437, 2001

Chakrabarti, A., Sarkar, P., Leelavathamma, B., Nataraju, B.S. A Functional Representation for Aiding Biomimetic and Artificial Inspiration of New Ideas, AI EDAM 19(2): 113-132, 2005

Research Story 3…

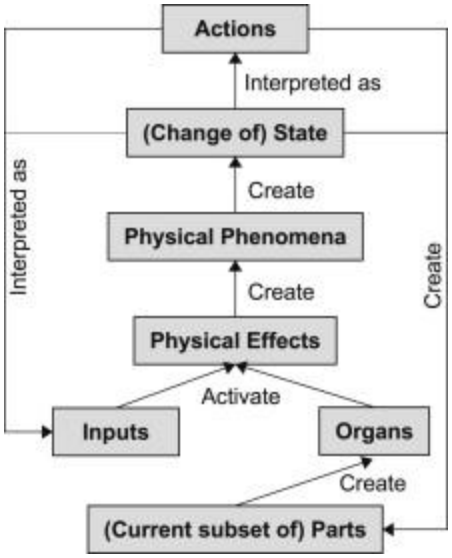

Image Credit: Chakrabarti et al., 2005

…Srinivasan and Chakrabarti [2010] found that SAPPhIRE model could be used to explain both analysis and synthesis. A hypothesis was SAPPhIRE levels were the levels of outcome abstraction in designing. If this were true, SAPPhIRE levels should be those described as general to specific levels by Nidamarthi et al., and of so, **design protocols must contain requirments and solutions at each level of SAPPhIRE**, and in no outcome levels other than these. This is what was found, which further confirmed the theory of co-evolution, that SAPPhIRE levels described levels of outcome abstraction, and that each general and specific levels in Nidamarthi's work belonged to one SAPPhIRE level of abstraction.

Srinivasan, V., and Chakrabarti, A. An Integrated Model of Designing, Special Issue on Knowledge Based Design, Ashok K. Goel and Andrés Gómez de Silva Garza (eds.), ASME Journal of Computing and Information Science in Engineering (JCISE), 10(3), September 2010,

Validation: Theory-driven Prediction

- Theory used to generate new hypothesis: prediction
  - Theory: Requirements and solutions co-evolve
  - Theory: SAPPhIRE are the levels of outcome abstraction
  - Prediction: **Requirements and solutions should be found at all SAPPhIRE levels and no other outcome levels**
- Prediction is falsifiable
  - The Hypothesis has the possibility of being wrong
  - If there are levels of SAPPhIRE where requirements or solutions are not found, then SAPPhIRE are not the levels of abstraction
- Prediction is found to be correct
- Considered an evidence of truth of the theory