Why Systems Thinking is Not a Natural Act

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Four Things Every Engineer Should Know About Systems Thinking

1. Systems thinking is not a natural act
2. Western educational system is the biggest inhibitor to systems thinking
3. Systems thinking can be taught (but not to everyone, unfortunately)
4. The best way to develop your systems thinking abilities is through experiential learning
Inspiration

The Seven Secrets of How to Think Like A Rocket Scientist (Longuski 2010)

How to Think Like Leonardo da Vinci (Gelb 1998)

Secret #2: Work on the big picture

“Think of the end before the beginning”
Scientific Thinking

1. Scientists are constantly adding to knowledge, and less frequently, developing new concepts and theories.
2. Scientists already have a rich background of knowledge in their domain that they use as a foundation for their thought.
3. Much creativity occurs in groups rather than the individual.

“Utilizing modal elements to consider the componential, relational, contextual, and dynamic elements of the system of interest.”

“Maybe pushing on that wall to the right will give some space.”
"Oops!"
Systems Thinking: A Latent Construct

• Five learning disciplines (Senge 1990)
  – Personal mastery, mental models, shared vision, team learning and systems thinking

• Seven critical skills of systems thinking (Richmond 1993)
  – Dynamic, closed-loop, generic, structural, operational, continuum, and scientific

• Thirty systems thinking laws (Frank 2000)
  – Synergy, gradual process, life-cycle thinking, solution exploration, etc.

• Four foundations of systems methodology (Gharajedaghi 2006)
  – Holistic thinking, operational thinking, systems theories and interactive design
Systems Thinking is not...

Creative *thinking*

System *doing*

*superhuman* ability

*A natural* act

Systems thinking is the ability to...
Systems Thinking Competencies

1. Ability to define the “universe” appropriately – the system operates in this universe
2. Ability to define the overall system appropriately – defining the right boundaries
3. Ability to see relationships – within the system and between the system and universe
4. Ability to see things holistically – within and across relationships
5. Ability to understand complexity – how relationships yield uncertain, dynamic, nonlinear states and situations
6. Ability to communicate across disciplines – to bring multiple perspectives to bear
7. Ability to take advantage of a broad range of concepts, principles, models, methods and tools – because any one view is inevitably wrong

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Measures of Systems Thinking

• Aptitude tests (Toshima 1993)
• Changes in mental models (Doyle, et al. 2008)
• Performance on management flight simulators (Sweeney & Sterman 2000)
• Application of knowledge, skills and behaviors in the classroom (Frank 2010)
Why is systems thinking not a natural act?

• Human evolution has favored mechanisms tuned to dealing with immediate surface features of problems
  – “programmed” human tendencies
• Mechanistic/reductionist approach in decision making
  – Driven by education
• Complexity of the systems overwhelms our cognitive capabilities
  – Bounded rationality, predictably irrational
  – Magic number 7, plus or minus two

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# Examples of Systems Thinking

<table>
<thead>
<tr>
<th>Essential Phenomena</th>
<th>Human Abilities</th>
<th>Human Limitations</th>
<th>Enhancing/ Overcoming</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimation: How to assess what is happening or will happen?</td>
<td>Good at recognizing familiar patterns and mapping to action</td>
<td>Inaccurate mental models and perceptions of the state of the process</td>
<td>Stochastic forecasting models and displays of filtered, smoothed &amp; predicted states</td>
</tr>
<tr>
<td>Stakeholders: How should stakeholders’ interests be balanced?</td>
<td>Good at specifying interests and importance of associated attributes</td>
<td>Difficult to deal with stakeholders’ differing and conflicting interests</td>
<td>Multi-stakeholder, multi-attribute models that enable tradeoffs and decisions</td>
</tr>
<tr>
<td>Future: How should future uncertainties be considered?</td>
<td>Good at imagining alternative futures and possible consequences</td>
<td>Difficult to consider future contingencies and specify long-term returns</td>
<td>Decision models that provide economic assessments of the value of contingencies</td>
</tr>
<tr>
<td>Challenges: How should management challenges be addressed?</td>
<td>Good at running the “as is” business to achieve familiar objectives</td>
<td>Tendency to be tactical rather than strategic &amp; too focused to see situation</td>
<td>Toolkits that enable systematic addressing &amp; pursuit of the essential challenges</td>
</tr>
<tr>
<td>Change: How should fundamental change be pursued?</td>
<td>Good at articulating a vision and leading people in pursuing this vision</td>
<td>Difficult to recognize forces for change and then commit to change</td>
<td>Methods that address value deficiencies, work processes, decisions &amp; social networks</td>
</tr>
</tbody>
</table>

Rouse, W. B., People and organizations: explorations of human-centered design, Wiley 2007.
Augustine’s Fifth Law
One-tenth of the participants produce over one-third of the output. Increasing the number of participants merely reduces the average output.

Brooks’ Law

Adding people to a late project makes it later

13-story Building in Shanghai

美丽的
莲花河畔景苑大楼
是怎样倒塌的
莲花河畔景苑施工方案
先造楼，后造地下车库

开挖地下车库

堆土

堆土挤压
创造世界房屋倒塌奇迹
Inhibitors to Systems Thinking

• Western educational system
  – No system thinker left behind

• Environment/institutional constraints
  – Incentives, tradition

• Work organization
  – Over-specialized job function

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# Systems Thinking Interventions

<table>
<thead>
<tr>
<th>Study</th>
<th>Sample population (n); Intervention (time)</th>
<th>Systems thinking measure(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Huz, et al. (1997)</td>
<td>Mental health professionals in New York (n = 18); System dynamics model building by a group (t = 6 months)</td>
<td>(1) Participants’ perceptions of the intervention, (2) Shifts in participants’ goal structure, (3) Shifts in participants’ change strategies, (4) Alignment of participant mental models, (5) Shifts in understanding how the system functions, (6) Shifts in network of agencies that support services integration, (7) Changes in system-wide policies and procedures, and (8) Changes in outcomes for clients.</td>
</tr>
<tr>
<td>Cavaleri &amp; Sterman (1997)</td>
<td>Insurance claims professionals (n = 70); Beer Game (t = not reported)</td>
<td>(1) changes in personal perceptions, (2) changes in behavior, and (3) competency in understanding the principles of the Beer Game</td>
</tr>
<tr>
<td>Sweeney &amp; Sterman (2000)</td>
<td>University students (n = 225); Bath tub and cash flow exercises (t = 2 weeks)</td>
<td>(1) feedback, (2) delays, and (3) stocks and flows.</td>
</tr>
<tr>
<td>Witjes, et al. (2006)</td>
<td>7-10 year old children in rural Colombia (n = 22); construction of a rain water recollection system and organic vegetable garden (t = 5 months)</td>
<td>Interpretation of drawings in terms of three systems thinking levels: (1) systems, subsystems and synergy, (2) possessiveness and feedback, and (3) chaos and order.</td>
</tr>
<tr>
<td>Doyle, et al. (2008)</td>
<td>University students (n = 46); Simulation of the economic long wave model (t = 2 weeks)</td>
<td>changes in (1) mental models and (2) feedback thinking</td>
</tr>
</tbody>
</table>
Mental Models in Rural Colombia

A Glimmer of Hope from Religion & Education

• Buddhism
  – Systems view as a systems experience
  – Appropriate level of analysis for any problem
  – Cause and effect (karma)
  – Cycles and continuous flowing (Sangsara)
  – Constant flux due to external conditions (Annica)

• Scientific Habits of Mind
  – Systems based reasoning
  – Model based reasoning
  – Understanding feedback

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What you can do: Be like Mike

• Understand complexity
• Develop prototypes before full scale production
• Focus on the human as a key element of the design
• Combine methods to arrive at the optimal solution

Experience Accelerators

• Management Flight Simulator

http://scripts.mit.edu/~jsterman/climate/master/
Healthcare Reborn
(http://www.healthcarereborn.com)

Tied for 1st place in Stevens Institute of Technology Experience Accelerator Competition (www.experience--accelerator.org)
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There are some questions that can’t be answered by Google.