A systems literacy manifesto
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A Systems Literacy Manifesto

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“...there is a good deal of turmoil about the manner in which our society is run...
....the citizen has begun to suspect that the people who make major decisions that affect our lives don’t know what they are doing.
...because they have no adequate basis to judge the effects of their decisions.”

— C. West Churchman, 1968
“Government is not the solution to our problems; government is the problem.”

— Ronald Reagan, 1981
“Those of us who have looked to the self-interest of lending institutions to protect shareholders’ equity, myself included, are in a state of shocked disbelief.”

— Alan Greenspan, 2008
“I do not believe that human activity is causing these dramatic changes to our climate the way these scientists are portraying it…”

— Marco Rubio, 2014
(U.S. Senator and candidate for President)
Decision makers “not knowing what they are doing,” lacking “adequate basis to judge effects,” is not stupidity. It is a type of illiteracy. It is a symptom that something is missing in public discourse, in organizations and businesses, and in our schools.
A Systems Literacy Manifesto

We need systems literacy—in decision makers and in the general public.

A body of knowledge has grown about systems; yet schools largely ignore it.

It can be codified and extended.

And it should be taught in design and management schools in particular, but also in general college education and in kindergarten through high school, just as we teach language and math at all levels.
PART ONE

Why do we need systems literacy?
Almost all the challenges that really matter involve systems, e.g.,

- Energy and global warming
- Water, food, and population
- Health and social justice
And in the day-to-day world of business, new products that create high value almost all involve systems, too.
For the public, for managers, and for designers, part of the difficulty is that these systems are

- **complex**
  made of many parts, richly connected

- **evolving**
  growing + interacting with the world

- **probabilistic**
  easily disturbed + partly self-regulating
  (not chaotic, but not entirely predictable)
The difficulty is compounded because these systems may not appear as “wholes”.

Unlike an engine or a tornado or a human being, they may be hard to see all at once.
Systems are often dispersed in space, their “system-ness” experienced only over time, rendering them almost invisible.

Or we may live within these systems seeing only a few individual parts, making the whole easy-to-overlook.

We might call these “hidden” systems—or gossamer or ethereal or translucent systems.
For example,

- **natural** system
  the water cycle, weather, and ecologies

- **information** system
  operating systems, DNS, cloud-based services

- **social** system
  languages, laws, and organizations

- **hybrid** system
  local health-care systems and education systems
Water travels continuously through a cycle.
Carbon also travels through a cycle.
Sometimes large quantities can be tied up—sequestered—so that they are not traveling through the cycle.

Changing stock levels—sequestering or releasing water or carbon—affects the climate as ice or carbon dioxide interacts with the planet’s weather system.
In sum:

We face the difficulties of untangling messes (taming wicked problems) and fostering innovation (economic and social), which require understanding systems—

which are complex, evolving, and probabilistic—

and “hidden” or “translucent”.

What is more: systems are “observed”.
“Anything said is said by an observer.”

— Humberto Maturana, Theorem Number 1, 1970

That is, as Stafford Beer said, “a system is not something given in nature,” it is something we define—even as we interact with it.
“Anything said is said to an observer.”

— Heinz von Foerster, Corollary Number 1, 1979

What the observer “says” is a description, said to another observer in a language (they “share”), creating a connection that forms the basis for a society.
Now, we can ask a simple question: How should we describe systems?

Or more precisely, how should we describe systems that are *complex, evolving, probabilistic*— and *“hidden”*—and *“observed”*?
PART TWO

What is systems literacy?
Churchman outlines four approaches to systems:

- **efficiency expert:**
  reducing time and cost

- **scientist:**
  building (mathematical) models

- **humanist:**
  looking to our values

- **anti-planners:**
  living *in* systems, not imposing plans
We might consider a fifth approach:

designer: prototyping and iterating systems or representations of systems
Basic systems literacy includes:

- **vocabulary** (content):
  a set of distinctions and entailments (relationships)

- **“reading”** (skills of analysis):
  recognizing common patterns in specific situations
  e.g., identifying—finding and naming—a control loop

- **“writing”** (skills of synthesis):
  describing the function of systems to others,
  mapping and diagramming
Systems literacy is enriched with:

- **literature:**
  a canon of key works of theory and criticism

- **history:**
  context, sources, and development of key ideas

- **connections:**
  conversations among and between disciplines
  e.g., design methods and management science
A vocabulary in systems begins with

- system, environment, boundary
- stocks, flows, delay (lag)
- source, sink
- process, transform function, cycle
- information (signal, message),
- goal (threshold, set-point), feedback

- circular processes, circularity
- closed-loop, open-loop
- viscous cycle, virtuous cycle
- explosion, collapse, dissipation
- negative feedback, positive feedback
- reinforcing, dampening, balancing
- stability, invariant organization,
- dynamic equilibrium, homeostasis
- tragedy of the commons

- behavior, action (task), measurement
- range, resolution, frequency
- sensor, comparator, actuator (effector)
- current state, desired state
- error, detection, correction
- disturbances, responses

- controlled variable, command signal
- servo-mechanism, governor
- hunting, oscillation, prediction
- control, communication
- teleology, purpose
- goal-directed, self-regulating
- co-ordination, regulation
- emergence
- feedforward
- static, dynamic
- first order, second order
- essential variables
- variety, “requisite variety”
- transformation (table)
- autopoiesis
- constructivism
- recursion

- observer, observed
- controller, controlled
- agreement, (mis-)understanding
- “an agreement over an understanding”
- learning, conversation
- bio-cost, bio-gain
- back-talk

- structure, organization,
- co-evolution, drift
- black box
- explanatory principle
- “organizational closure”
- self-reference, reflexive
- ethical imperative
- “generosity in design”
- structural coupling
- “consensual co-ordination of consensual co-ordination”
- “conservation of a manner of living”
Reading systems means recognizing common patterns in specific situations.

 e.g.,
 - resource flows and cycles
 - transform functions (processes)
 - feedback loops
 - feed-forward
 - requisite variety
 - second-order feedback
 - goal-action trees
Consider the toilet and thermostat, different in form and structure.
Yet the toilet and thermostat are the same in function. Both are governors.

Goal = water level at 10 cm

Goal = temperature at 18°C

Measure water level

Action open valve

Tank

Measure temperature

Action activate heater

Air in the room
Writing systems means describing the function of systems to others, through

- text
- images
Text can describe a system’s function, linking it to a common pattern.

But text descriptions require mental gymnastics from readers—*imagining* both the behavior of the system and the abstract functional pattern—*and* then linking the two.
Images of physical systems aid readers, though behavior can be difficult to depict.

But function must be represented in diagrams, often with some degree of formalism.

Learning to read and write one or more systems function formalisms is an important part of systems literacy.
Donalla Meadows has a particular formalism.
O’Connor & McDermott have another formalism.

- Reinforcing
- Balancing
- Limits to Success
- Addiction
Otto Mayr has a block diagram formalism.
Yet in many cases, simple concept maps may be all the formalism required.

Feedback: Overview

- **Goal** (Desired State)
- **Effect** (Current State)
- **Action**
  - System attempts to reach a goal; based on feedback, it modifies its actions. (System acts both within itself and on its environment.)
- **Measurement**
  - System measures its progress comparing current state to desired state determining the difference, and attempting to correct the ‘error.’
- **Feedback** (transfer of information)
  - Through system
  - Through environment
Yet in many cases, simple concept maps may be all the formalism required.

Feedback: Mechanism

System

Goal describes a relationship that a system desires to have with its environment

Environment

Disturbances may be characterized as certain types typically falling within a known range; but previously unseen types may emerge and values may vary beyond a known range; in such cases the system will fail because it does not have requisite variety

Comparator

subtracts the current state value from the desired state value to determine the error

System

Sensor passes the current state value to a Comparator . . . . . . . . . . responds by driving an Actuator

Actuator

. . . has resolution – (Accuracy)
frequency – (Latency)
range – (Capacity)

Feedback: Mechanism

input

is measured by

output

a Sensor passes the current state value to a Comparator . . . . . . . . . . responds by driving an Actuator

Actuator

. . . has resolution – (Accuracy)
frequency – (Latency)
range – (Capacity)

System

Environment

Disturbances . . . may be characterized as certain types typically falling within a known range; but previously unseen types may emerge and values may vary beyond a known range; in such cases the system will fail because it does not have requisite variety
Netscape search concept map
A heart attack is a blockage of blood flow to the heart, which results from build up of plaque in the arteries of the heart, which results from risk factors some of which can be controlled by behavior.

Risk factors: unhealthy living (taking prescribed medications, controlling such as lowering blood pressure, reducing stress), diabetes, obesity, physical inactivity, heredity (including being African-American), under age 55, being male over age 65, being female, increasing age, tobacco exposure, high cholesterol (also called hypercholesterolemia, from Greek huper, over, khole, bile and stereos, solid), high blood pressure (also called hypertension, from Greek huper, over, and Latin tensis, stretching out), controllable risk factors (which results from some of which can be controlled by behavior) diabetes, obesity, physical inactivity, heredity (including being African-American), under age 55, being male over age 65, being female, increasing age, tobacco exposure, high cholesterol (also called hypercholesterolemia, from Greek huper, over, khole, bile and stereos, solid), high blood pressure (also called hypertension, from Greek huper, over, and Latin tensis, stretching out), uncontrollable risk factors (which results from some of which can be controlled by behavior).

Diagnoses: build up of plaque (also called atherosclerosis, from Greek athero, meaning gruel or paste, and sclerosis, meaning hardness), risk factors (which results from some of which can be controlled by behavior).

Symptoms: high cholesterol (also called hypercholesterolemia, from Greek huper, over, khole, bile and stereos, solid), high blood pressure (also called hypertension, from Greek huper, over, and Latin tensis, stretching out), controllable risk factors (which results from some of which can be controlled by behavior) diabetes, obesity, physical inactivity, heredity (including being African-American), under age 55, being male over age 65, being female, increasing age, tobacco exposure, build up of plaque (also called atherosclerosis, from Greek athero, meaning gruel or paste, and sclerosis, meaning hardness), risk factors (which results from some of which can be controlled by behavior).

Diagnosis: high cholesterol (also called hypercholesterolemia, from Greek huper, over, khole, bile and stereos, solid).
Weight control concept map

Gender: Female = \((4.35 \times CW) + (4.7 \times H) - (4.7 \times A)\)
Gender: Male = \((4.23 \times CW) + (12.7 \times H) - (6.8 \times A)\)

Current weight: \(cW\)
Recommended weight: \(rW\)
Goal weight: \(gW\)

\(\Delta W\) Weight change
\(\Delta T\) Time to reach goal weight

\(R\) Rate of weight loss per day
\(3500\) Calories in 1 lbs

\(C+\) Calories eaten/day
\(C-\) Calories burned/day

BMR Basal metabolic rate
AF Activity factor

Can't be > 2 lbs/week (or .286 lbs/day)
Defaults to 1 lbs/week (or .143 lbs/day)
Drug delivery device map

- Temperature
  - Concentration
    - Needle Gauge
      - Needle Strength
        - Injection Depth
        - Needle Length
          - Cost
            - Flow Rate
              - Time
                - Volume
                  - Pain

- Concentration
- Needle Gauge
- Needle Strength
- Injection Depth
- Needle Length
- Flow Rate
- Time
- Volume
- Pain

Proportional
Inverse
More accurately...

Drug delivery device map
**Email conceptual model**

<table>
<thead>
<tr>
<th>Accounts such as</th>
<th>- AOL</th>
<th>- Exchange</th>
<th>- Gmail</th>
<th>- Hotmail</th>
<th>- iCloud</th>
<th>- Ymail</th>
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</thead>
<tbody>
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<td>can include</td>
<td>Mail boxes</td>
<td>can be accessed by</td>
<td>Email Client</td>
<td>- Added</td>
<td>- Logged into</td>
<td>- Logged out</td>
</tr>
<tr>
<td>can be accessed by</td>
<td>Email Client</td>
<td>- Fetch and Push</td>
<td>- Auto and Manual</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Message can be</td>
<td>- Created</td>
<td>- New</td>
<td>- Manually</td>
<td>- From template</td>
<td>- Reply</td>
<td>- Reply All</td>
</tr>
<tr>
<td>Threads (Conversations) can be</td>
<td>- Created</td>
<td>- Quoted</td>
<td>- Quoted by template</td>
<td>- By Microphone (hand-in-hand)</td>
<td>- Drafted</td>
<td>- Annotated</td>
</tr>
<tr>
<td>can be</td>
<td>- Created</td>
<td>- New</td>
<td>- Manually</td>
<td>- From template</td>
<td>- Reply</td>
<td>- Reply All</td>
</tr>
<tr>
<td>Preferences can be</td>
<td>- Primary Account</td>
<td>- Notification</td>
<td>- Sound</td>
<td>- By Account</td>
<td>- By Sender</td>
<td>- Prevent flooding</td>
</tr>
<tr>
<td>can be organized in</td>
<td>Fields</td>
<td>can be</td>
<td>- Created</td>
<td>- Drafted</td>
<td>- Saved</td>
<td>- Edited</td>
</tr>
<tr>
<td>Hot Strings can be</td>
<td>- URLs (Auto-formed links)</td>
<td>- Dates (Calendar events)</td>
<td>- Names (Contacts)</td>
<td>- Phone numbers</td>
<td>- Addresses</td>
<td>can be</td>
</tr>
<tr>
<td>Images can be</td>
<td>Attached</td>
<td>- Hidden</td>
<td>- Hidden by default</td>
<td>- Hidden by sender</td>
<td>- Hidden by receiver</td>
<td>can be</td>
</tr>
<tr>
<td>Local memory includes</td>
<td>Cloud</td>
<td>Gallery</td>
<td>Quick Office</td>
<td>Document to go</td>
<td>Social networks (later)</td>
<td></td>
</tr>
<tr>
<td>Related Features may include</td>
<td>- Contacts</td>
<td>- Calendar</td>
<td>- Bookmarks</td>
<td>- Reminders (To-dos)</td>
<td>- Documents (Files)</td>
<td>- Media (e.g., books, music, video)</td>
</tr>
<tr>
<td>can include</td>
<td>Accounts</td>
<td>can be organized in</td>
<td>- Folders</td>
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<td>User Name and Password are associated with</td>
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<td>User Name</td>
<td>Email Address</td>
<td>User Name</td>
<td>Password</td>
<td>Server</td>
</tr>
<tr>
<td>can be configured for</td>
<td>IMAP / POP</td>
<td>for Exchange</td>
<td>- Auto</td>
<td>- SSL/TLS</td>
<td>- STARTTLS</td>
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</tr>
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<td>Configured</td>
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<td></td>
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<td></td>
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<tr>
<td>can be</td>
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</table>

**Dubberly Design Office - A Systems Literacy Manifesto - 17 October 2014**
Disney map
PART THREE

How do we achieve systems literacy?
Teaching systems in design is not a new idea. HfG Ulm had courses in operations research and cybernetics in the 1960s.
All graduate design programs should have courses in systems literacy—as should under grad programs in

- product design
- interaction design
- service design
- information design
- and any program in innovation or social entrepreneurship
One course, 3 hours per week for 12 to 15 weeks is a bare minimum survey of systems.

Ideal would be 3 semesters:

- **Intro to Systems:**
  systems dynamics, regulation, requisite variety

- **Second-Order Systems:**
  observing systems, autopoiesis, learning, ethics

- **Systems for Conversation:**
  co-evolution, co-ordination, and collaboration
Recommended readings:

- *A Systems View of Life*, Capra
- *Thinking in Systems*, Meadows
- *An Introduction to Cybernetics*, Ashby
- “Second-order Cybernetics,” Glanville
- “Ethics and Second-order Cybernetics,” von Foerster
- “Systemic and Meta Systemic Laws,” Maturana + Davila
- “What is conversation?” Pangaro
- “The Limits of Togetherness,” Pask
- *Decision and Control*, Beer
- “Meta-design,” Maturana
Recommended format: seminar + studio

- Readings and discussions
- Review of common patterns (via canonical diagrams)
- In class exercises to apply the patterns
- Homework to apply the patterns again
- In class critiques of previous week’s homework
- Final project to design a new system
  or repair (or improve) a faulty one
Literacy requires fluency in a language.

As with any language, learning the language of systems requires immersion, practice, and time.

The reward is that practice becomes habit, and habit becomes a way of thinking—an other (another) point of view.
Implications of (and for) observing systems
“Designers need to be able to observe, describe, and understand the context and environment of the design situation...

...a designer is obliged to use whatever approaches provide the best possible understanding of reality...”

— Harold Nelson, Erik Stolterman
“Pask... distinguishes two orders of analysis.

The one in which the observer enters the system by stipulating the system’s purpose...

[the other] by stipulating his own purpose...
[and because he can stipulate his own purpose]

he is autonomous...
[responsible for] his own actions...”

— Heinz von Foerster, 1979
“...if we know that the reality that we live arises through our emotioning, and we know that we know, we shall be able to act according to our awareness of our liking or not liking the reality that we are bringing forth with our living.

That is, we shall become responsible of what we do.”

— Humberto Maturana, 1997
“We human beings can do whatever we imagine if we respect the structural coherences of the domain in which we operate.

But we do not have to do all that we imagine, we can choose, and it is there where our behavior as socially conscious human beings matters.”

— Humberto Maturana, 1997
We have a responsibility to try to make things better.

If we want decision makers to have a basis to judge the effects of their decisions, or if we acknowledge that almost all the challenges that matter—and most social and economic innovation—involve systems, and if we know that tools exist to help us think about systems, then we must put those tools into circulation.

We must build systems literacy. To not do so would be irresponsible.
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www.dubberly.com/presentations/system_literacy.pdf