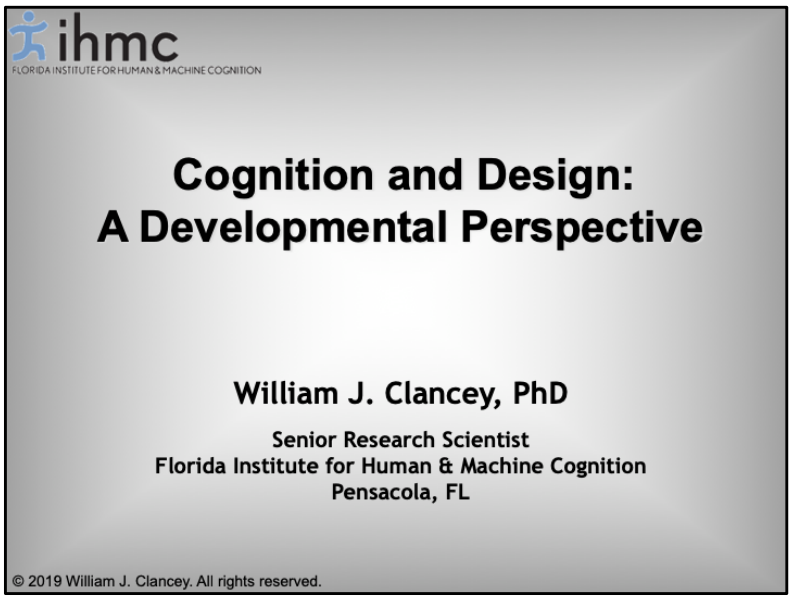
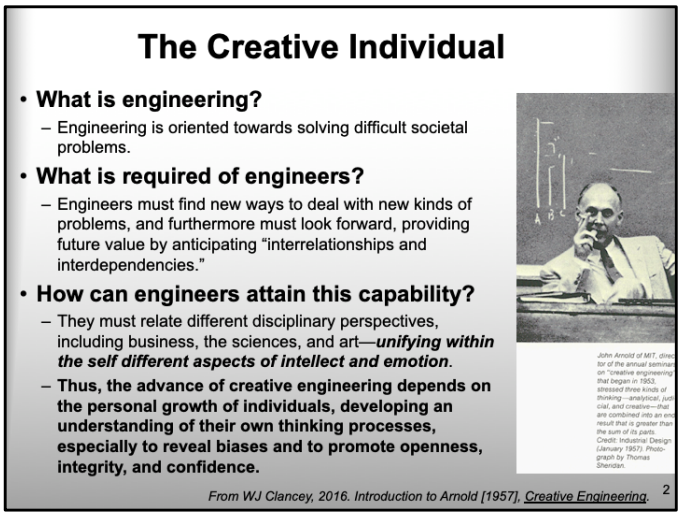


The Stanford Neurodesign Symposium was held March 6, 2019. I was invited to speak on the topic “Cognition and Design.” I chose to present a broad synthesis relating neuro-psychology and design activities through a developmental perspective.

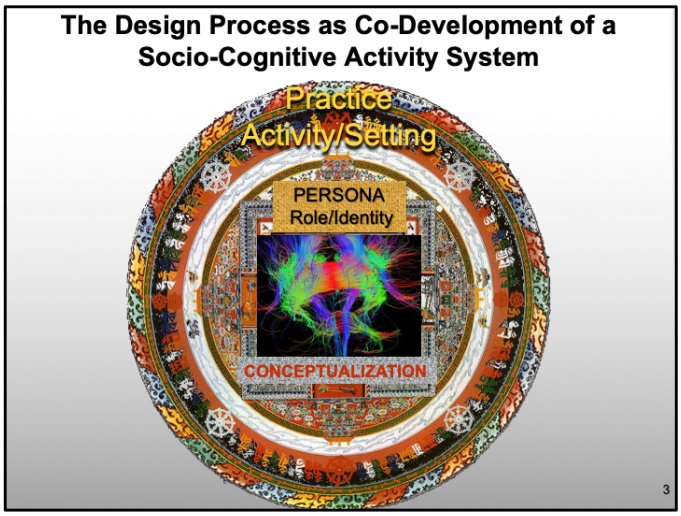


(Text adapted from J.E. Arnold, "Creative Engineering," talk delivered to the third M.I.T. Mid-west Conference, Saturday, Feb. 26, 1955 at the Mid-Day Club, Cleveland, Ohio.)

John Arnold's focus on personal growth provides a way to relate neuro-psychology and design. Arnold was a psychologist in the 1950s. Respecting the concerns of his profession and the cultural context, he emphasized an individual perspective on the nature of creativity.

Arnold begins by asking, *"What is engineering?"* Engineering is oriented towards solving difficult societal problems. *"What is required of engineers?"* Engineers must find new ways to deal with new kinds of problems, and furthermore must look forward, providing future value by anticipating "interrelationships and interdependencies" fostered by the burgeoning population—"two thirds of the world's population goes hungry" (*Creative Engineering*, "Creative Product Design," p. 127). *"How can engineers attain this capability?"* They must relate different disciplinary perspectives, including business, the sciences, and art—and this requires unifying within the self different aspects of intellect and emotion. Thus, the advance of creative engineering depends on the personal growth of individuals, developing an understanding of their own thinking processes, especially to reveal biases and to promote openness, integrity, and confidence.

I discuss in the Introduction to *Creative Engineering* (see references) how the milieu shaped Arnold's focus on the individual. From today's perspective, we might ask, what has been lost by focusing design research on the team? How can we bring these analytic perspectives into balance in our theories of design and learning? In particular, how might we formulate personal growth in terms of both neuro-psychological processes and social activity?

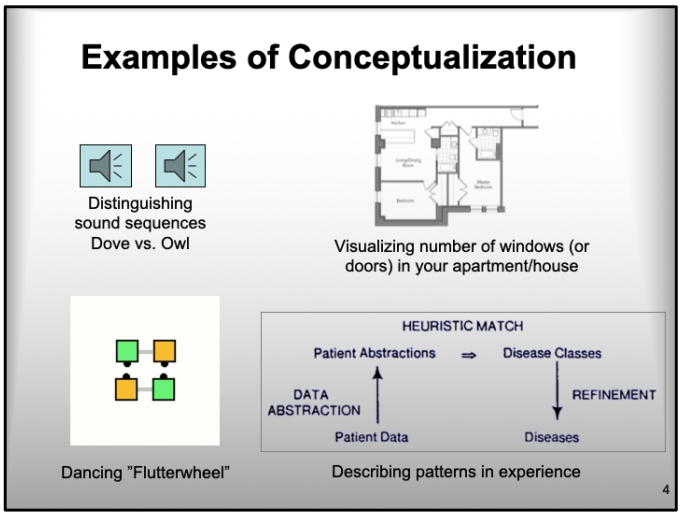


In this talk, I suggest how we might bring together the neural, personal, and social perspectives on cognition, illustrated by this Jungian Mandala, which suggests a wholistic view. I am interested in what influences and constrains the development of ideas in the individual and in groups. Can we relate the neural processes of **conceptualization** (involving categorization, association, sequencing, and composition of neural processes); the construction of a **persona** (especially with respect to social-interactive roles); and **practices** (reflectively using designed tools, artifacts, and other aspects of activity systems in physical-social settings over time)? These are three levels of organization within a single system; they are self-regulated processes that develop together, influencing each other in a dependent way. Memory is an essential aspect for each subsystem, but its nature changes from neurons to concepts to cultural artifacts (including representations). Similarly, feedback processes within and across levels, serving to construct, reinforce, and adapt how each system organizes itself; but the neuronal, semantic, and social-interactive systems maintain their own integrity in different ways.

From Wikipedia regarding "Mandala: Western psychological interpretations"
In his autobiography, Jung wrote: "I sketched every morning in a notebook a small circular drawing, ... which seemed to correspond to my inner situation at the time. ... Only gradually did I discover what the mandala really is: ... the Self, the wholeness of the personality, which if all goes well is harmonious." *— Carl Jung, Memories, Dreams, Reflections, pp. 195–196.*

Jung recognized that the urge to make mandalas emerges during moments of intense personal growth. Their appearance indicates a profound re-balancing process is underway in the psyche. The result of the process is a more complex and better integrated personality.
The mandala serves a conservative purpose—namely, to restore a previously existing order. But it also serves the creative purpose of giving expression and form to something that does not yet exist, something new and unique. ... The process is that of the ascending spiral, which grows upward while simultaneously returning again and again to the same point. *— Jungian analyst Marie-Louise von Franz, C. G. Jung: Man and His Symbols, p. 225*

Creating mandalas helps stabilize, integrate, and re-order inner life.[35] According to the psychologist David Fontana, its symbolic nature can help one "to access progressively deeper levels of the unconscious, ultimately assisting the meditator to experience a mystical sense of oneness with the ultimate unity from which the cosmos in all its manifold forms arises."[36]

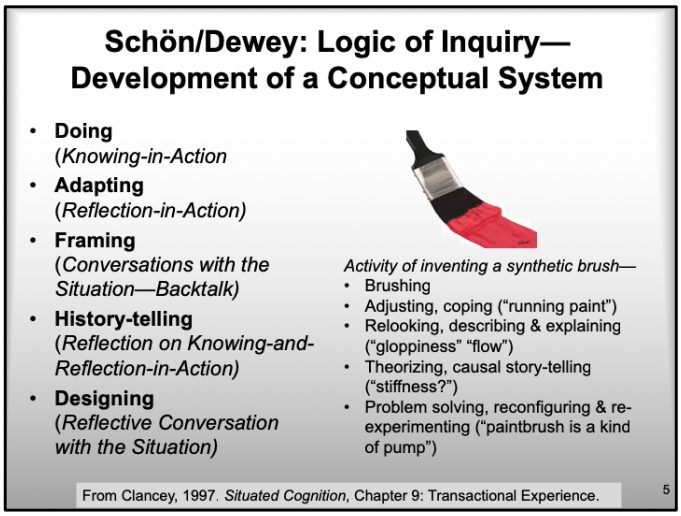


In my opinion the greatest shortcoming of the discipline of Cognitive Science since its formation 40 years ago is in understanding the neuro-psychological nature of conceptualization. Most theories of reasoning, problem solving, learning, etc. model concepts as things with properties (e.g., schemas, semantic networks). But concepts are processes, "doing something all the time" (Bartlett, 1932; see *Conceptual Coordination* (Clancey 1999) for a model of a "process memory"; see also my *Behavioral & Brain Sciences* reviews on my web site).

Simply put conceptualization is a generalization of the processes of perceptual categorization and perceptual-motor coordination — it is the brain operating on (categorizing) its own constructions. This higher-order process involves categorizing internally across modalities (e.g., image and sound), categorizing temporally to construct sequences (aka "chunking"), and categorizing sequences to construct hierarchical compositions (e.g., skills). A dynamic blending process enables ordering one composition by another in real-time (e.g., grammatical speech). Emotion (concern, interest) is a fundamental aspect of this conceptual coordination process.

In summary, the human brain is a marvelous "process creating" system that learns, remembers, and adapts while in activity itself. Our computational models of this process are woefully incomplete; we won't understand "intelligence" (or create an artificial form of it) until we can properly characterize and model conceptualization.

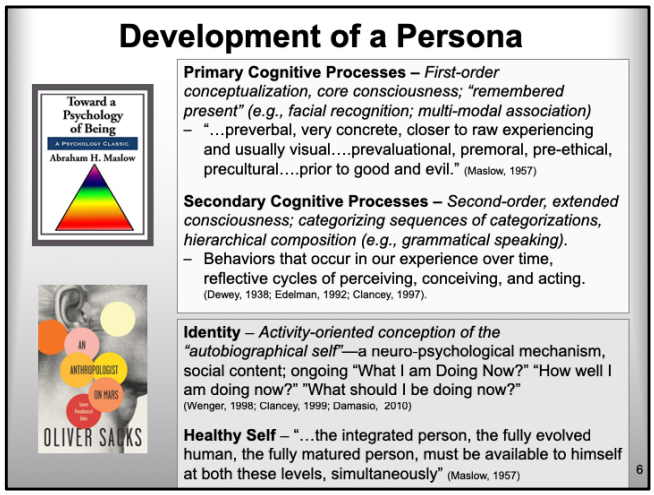
In this slide I present four examples of our conceptualization abilities – recognizing a sound sequence (which relates as well to hearing words), learning sequences in dancing (involving sequential kinesthetic-visual processes), spatial visualization of well-known places, and of course verbal conceptualization (here illustrated as an abstract schema for describing expert systems, "heuristic classification"). A key point is that these modalities – sounds, images, gestures, utterances – are conceptually coordinated in space-time. Singing provides an excellent example, relating emotion, pitch, and rhythm with meaning. With respect to Stanford's Neurodesign Research Program, my interest is in relating conceptualization to neural processes.



Donald Schön's notion of a "reflective practitioner" provides a way of understanding how conceptual systems develop—neurologically, for individuals, and in teams. See *Situated Cognition* for elaboration and further discussion of Schön's analysis of the paintbrush inventors. In this excerpt from p. 216, Schön's terms are in italics; my preferred terms in boldface:

- **Doing** (*Knowing-in-Action):* Attentive action occurs automatically, including both physical manipulation (as in painting) and talking (generating descriptions).
- **Adapting** (*Reflection-in-Action):* We are caught short momentarily, but easily continue. We "glitch" on something unexpected, but respond immediately, proceeding from another conceptual coordination (e.g., paint is running down the wall, but the problem is familiar and the recovery maneuver is practiced).
- **Framing** (*Conversations with the Situation (Backtalk)):* What are we talking about? What categorization fits our activity of speaking? We are transforming the conversation (deliberately attempting to generate appropriate descriptions of the situation). (The paint is all gloppy: What is going on? What is happening? Is it me or the brush or the wall or the paint or the humidity or ...)
- **History-telling** (*Reflection on Knowing-and-Reflection-in-Action):* We are articulating new theories, relating images to words, describing how we feel, reviewing what has been said so far (reflecting on a sequence of behavior and prior descriptions, composing past perceptions into a new way of seeing). ("It's almost like using a brush that wasn't properly cleaned—the bristles are too stiff.")
- **Designing** (*Reflective Conversation with the Situation):* We are deliberately guiding the conversation so it becomes an inquiry-project, resolving a problematic situation (defining what models should be about; creating and carrying out an activity involving the above four components to some end; representing what we intend to compose and then managing that composition process). (A paintbrush is a kind of pump.... Is a rag a pump, too?)

As we start to model a problematic situation, we describe things, states, and processes; we frame what is occurring by naming breakdowns in our activity, such as undesirable properties of things (cf. Stanford studies of design teams generating noun phrases). In history-telling we comment on a *sequence* of prior perceptions and descriptions, constructing a narrative with causal relations. Then we may theorize, plan (strategize), and/or reconfigure objects and activities—a process of *designing* that will change our tools, settings, and/or behaviors in practice.



So far I've focused on the neuro-psychological level of conceptualization. My framework is inspired by Edelman's *Bright Air, Brilliant Fire* (see my book review in *Contemplating Minds,* 1994). Conceptualization is the basis of consciousness, which both Edelman and Maslow call "primary" and "secondary." A simple view is that secondary consciousness involves holding active two or more categorizations and relating them by another categorization, as in logical-causal reasoning, noun references grammatical speech, planning, etc.—hence it is "higher-order" conceptualization (HOC). In simple terms, "identity" bridges neural and social systems. Identity is an ongoing conceptualization of "what I am doing now" etc. HOC makes teamwork possible by locating within the individual an understanding of roles, norms, etc. that are the essence of group activities and practices. At the same time, identity is a neuro-psychological/emotional phenomenon, a process regulating its own integrity and seeking "wholeness" across primary and secondary processes. Here I am drawing on Maslow's essay in Arnold's *Creative Engineering* seminar. I urge you to read my analysis in the Introduction to *Creative Engineering* and the essay itself. Here is an excerpt describing the primary processes (pp. 192–193):

"Deep down, we look at the world through the eyes of wishes and fears and gratifications. Perhaps it will help you if you think of the way in which a really young child looks at the world, looks at itself and at other people. It is logical in the sense of having no negative, no contradictions, no separate identities, no opposites, no mutual exclusions. Aristotle doesn't exist for the primary processes. It is independent of control, taboos, discipline, inhibitions, delays, planning, calculations of possibility or impossibility. It has nothing to do with time and space or with sequence, casualty, order, or with the laws of the physical world. This is a world quite other than the physical world. When it is placed under the necessity of disguising itself from conscious awareness to make things less threatening, it can condense several objects into one as in a dream. It can displace emotions from their true objects to other harmless ones. It can obscure by symbolizing. It can be omnipotent, ubiquitous, omniscient. (Remember your dreams, now. Everything I've said holds for the dream.) It has nothing to do with action for it can make things come to pass without doing or without acting, simply by fantasy. For most people it is preverbal, very concrete, closer to raw experiencing and usually visual. It is prevaluational, premoral, pre-ethical, precultural. It is prior to good and evil. Now, in most civilized people just because it has been walled off by this dichotomizing, it tends to be childish, immature, crazy, dangerous, frightening. Remember I've given you an example of the person who has completely suppressed the primary processes, completely walled off the unconscious. Such a person is a sick man in the particular way which I have described."

At the Institute for Research on Learning in the 1990s we defined learning as "becoming a member of a community of practice" (e.g., Wenger, 1998). Viewed from Arnold's individualistic perspective, we may wonder, "Why does a person want to join a particular community?" and "How might the person and community co-develop to enable participation?" I outline here how we can put these ideas together: Personal growth is conceived by individuals in social terms and enabled by group needs and opportunities. A sense of self develops by participating, contributing, defining, knowing; for a "healthy self" we need a sense of agency, of being efficacious. This is part of conceptualization of the self—needing feedback for closure about commitments, that is, confirmation from other people. The social assessment of our intentions and actions is fundamental to our construction of "Who I am being now" and "How well I am doing now" that are integral to our ongoing consciousness, our conceptualization of being alive, of being a social actor, a person.

In short, these aspects of life are co-developing: Group Activities (practices), Niche/Role of individual, Contributions, Capabilities, Agency, Identity, and Emotional assessment (e.g., happiness, discord, intimacy). At the same time, the group's capability, contribution, agency, mission, etc. are developing in a larger social-organizational landscape. In this Both–And synthesis the individual is not placed in opposition to the group; rather the individual-as-participant only exists (in such an activity) because of the team, and the team only exists because of the individual contributions. They are dependent on each for learning, creativity, and effective action (Wenger, 1998, pp. 149–163).

Thus, our study of the design process should not be framed as a choice between focusing on the team or the individual, but understanding how they develop together and depend on one another, and thus might be facilitated to leverage each other. Besides "How can we promote a certain conversation in the group?" we might also consider "What conversations do individuals need to have as part of their personal inquiries, projects, and desires?" Understanding the individual in this way requires understanding the nature of consciousness as a neuro-psychological process, which is tantamount to understanding the nature of conceptualization.

This brings us to design practice. "AI" as a discipline today is more than a body of programming techniques and algorithmic theory. A multidisciplinary community of computer scientists, psychologists, and social scientists have developed a design methodology for creating practical systems through iterative experiments with prototypes in authentic work settings.

An example of this design activity is our R&D effort at NASA to develop the voice-commanded agent system ("Mobile Agents") for future Mars astronauts, in which we experimented with prototype systems at the Mars Desert Research Station (MDRS) in Utah during 2002–2006. (In a plenary talk at the Mars Society Annual Convention August 2018, I related our work at MDRS to Arnold's *Arcturus IV Case Study*—we were not just designing for imaginary beings on another planet, but role-playing in a "mission simulation" of living and working on Mars.)

Here I've described MDRS in terms used by Douglas Thomas & John Seely Brown in *A New Culture of Learning: Cultivating the imagination for a world of constant change.* They characterize innovation as involving a combination of play and imagination. Of course you also need technical methods (e.g., knowledge of AI programming), design processes, and tools. You need to engage in a disciplined R&D approach. As in world-building games described in *A New Culture of Learning*, the simulated missions at MDRS provide a setting, experience, and learning environment that facilitates play and the imagination.

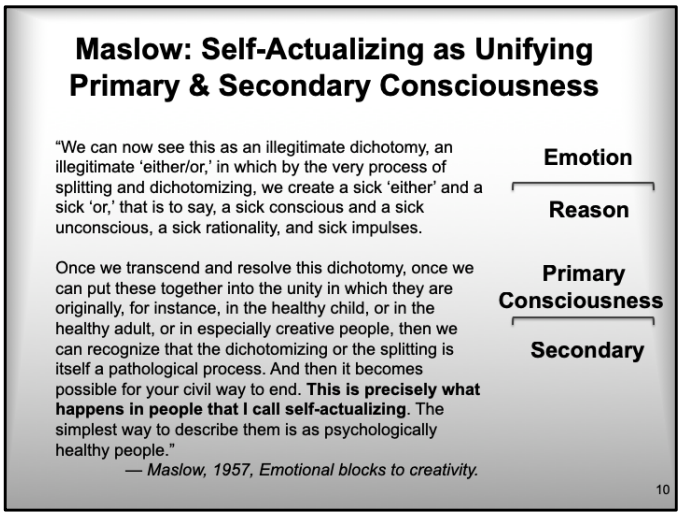
The relative absence of organizational constraints at NASA Ames and while at MDRS also facilitated our productivity; this falls within Arnold's category of "cultural blocks to creativity." We were well-funded and allowed to do our own thing, while NASA promoted our work in press releases and on the web site, affirming the organizational validity of our activities (see the table "Expedition Field Work & Experiments" at https://billclancey.name/WJCMarsSociety.html).

Regarding our R&D approach—we developed the Mobile Agents system iteratively in an annual cycle of prototype experiments, designing improvements with the geologists based on their experience while using the system to do real work in a setting that interested them.

Here you see some pictures of a simulated "extra-vehicular activity" (EVA—exploration outside the habitat wearing spacesuits), working on the upper deck of the MDRS "hab," and a Star Wars inspired sword fight by the two geologists who experimented with the Mobile Agents system—horsing around at the end of the day.

This last picture reminds me how we walked around with these transparent garbage can lids on our heads, never feeling silly, but allowing our imagination to take over, to become in our activity astronauts on Mars. We enjoyed the fantasy, we were spontaneous, authentic in this adopted identity, like kids playing—yet all the time carrying out serious state-of-the-art research. Videos document our accomplishments (see table cited on prior slide or search "wjclancey NASA" on YouTube.com).

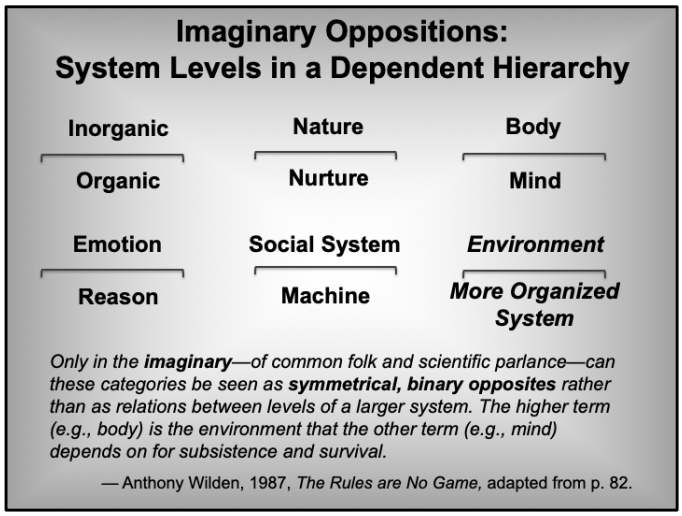
Maslow's perspective on play relates to our freedom from cultural blocks afforded by MDRS setting and expedition activity. Role playing in a group-sanctioned game allowing us to act out our ideas, to develop a future persona. Our conceptualization of "being on Mars" affected how we attended to and talked about our surroundings, the potential "Mars problems" we noticed and discussed, and the new tool designs we imagined. This adopted Martian persona made designing for Mars possible and productive. (See also my discussion of "The Personal Scientist" in the book *Working on Mars*, 2012.)



Self-actualizing is not bootstrapping, it is realizing your potential capabilities/skills in accord with your needs, desires, and intentions. But crucially, this occurs within an activity setting, by engaging with other people in a setting that affords creative action and hence growth. Maslow's remarks here are in accord with Arnold's view that understanding our own thinking enables us to be more creative. Maslow focuses on a prevalent misconception about the mind that views the primary and secondary processes as a dichotomy—being either emotional or rational, either having fun or doing something serious, etc. Instead, we can adopt a "both-and" perspective, illustrated by the diagrams on the right, in which **these processes are one system in dependent hierarchy**. Reason doesn't control emotion, but rather is dependent on it; concerns, worries, interests, desires, etc. provide the context that orients reason, making it purposeful and meaningful, and evaluating its products.

Chronologically, our knowledge of primary processes was derived first from studies of dreams and fantasies and neurotic processes, and later of psychotic, insane processes. Only little by little has this knowledge been freed of its taint of pathology, of irrationality, of immaturity, and primitiveness, in the bad sense. Only recently have we become aware, fully aware, from our studies of healthy people, of the creative process, of play, of aesthetic perception, of the meaning of healthy love, of healthy growing and becoming, of healthy education, that every human being is both poet and engineer, both rational and non-rational, both child and adult, both masculine and feminine, both in the psychic world and in the world of nature. Only slowly have we learned what we lose by trying daily to be *only* and *purely* rational, *only* "scientific," *only* logical, *only* sensible, *only* practical, *only* responsible. Only now are we becoming quite sure that the integrated person, the fully evolved human, the fully matured person, must be available to himself at both these levels, simultaneously. Certainly it is now obsolete to stigmatize this unconscious side of human nature as sick rather than healthy. That's the way Freud thought of it originally but we are learning different now. We are learning that complete health means being available to yourself at all levels. We can no longer call this side "evil" rather than "good," lower rather than higher, selfish rather than unselfish, beastly rather than human. Throughout human history and especially the history of Western civilization, and more especially the history of Christianity, has there tended to be this dichotomy. No longer can we dichotomize ourselves into a cave man and a civilized man, into a devil and a saint. We can now see this as an illegitimate dichotomy, an illegitimate "either/or," in which by the very process of splitting and dichotomizing, we create a sick "either" and a sick "or," that is to say, a sick conscious and a sick unconscious, a sick rationality, and sick impulses.

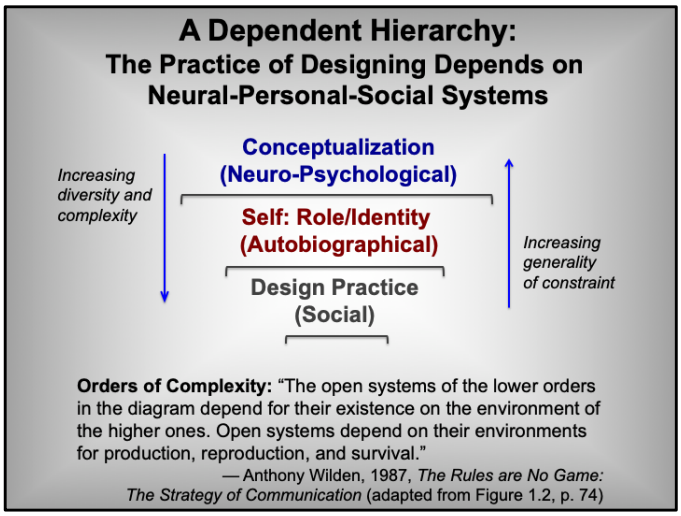
— Maslow, Emotional Blocks to Creativity, in *Creative Engineering*, pp. 194–195.



As Maslow states, dichotomizing dependent systems as independently existing forces, entities, ideas, etc. is a common framework that Western civilization has adopted for understanding nature and humanity. It has extended to how many scientists and engineers until recently understood organisms, the mind, and machines. I adopt here the notation and analytic perspective of Anthony Wilden (see the introduction to *Creative Engineering* for a more thorough presentation and explanation). In each of these diagrams, the environment or context for some activity/system is shown as above another system; they operate as a whole, but higher one makes the lower ones possible. The lower ones are more organized, more constrained, more complex; the upper ones are more general, more open to adaptation and external influences. Thus a person may be part of many communities of practice at one time or in a lifetime; but a given COP is relatively restricted with respect to the kinds of people who will fit within its roles and activities, both pragmatically and in terms of capabilities, habits, beliefs, values, etc.

Typically we conceive either-or relationships because a story of parts/factions and conflicts is easy to tell and understand causally. But the subsystems are dynamic and the interactive whole is complex. The constructs of human endeavor (including institutions, cultural practices, and tools) exist within a dependent hierarchy of processes that contextually motivate and give meaning to new inventions. From this perspective, a designer is called upon to know the world for which he/she is designing holistically, as feeling and fact together, in a relationship that is both logical and intuitive-emotional, critically probing and at the same time sensitively aesthetic.

We can view Wilden's notion of "constraints" here as being resources (e.g., guiding values, beliefs, perception, methods) that are the basis by which more organized systems can be develop with (or be designed for) certain purposes/intentions. Do not confuse constraints with "goals." Goals for a design project operate at the social-interactional level, they do not directly control the experiences and conceptualizations of the individuals involved—a collective constituting the "environment" in which design requirements are formulated and framed.



In this talk, I provided a framework for relating the neural, personal, and social perspectives as a whole so we might engage in research to understand how these systems co-develop. I have been asked, "What is the line of separation/inflexion that separates these processes/levels/systems?" By this *interactional* analytic framing, boundaries define independently existing components. In a *transactional* framing, we describe events and the trajectories of changing relationships, as for example, a design practice involves individuals carrying out and co-constructing roles within activities. (See *Situation Cognition*, pp. 175–178 & discussion of Maturana, pp. 75ff.)

Note the rule of "extinguishing" a level—without higher-order conceptualization, we lose our *autobiographical consciousness* (Damasio, p. 168) and our ability to carry out a practice, let alone design activity systems. Thus the neuro-psychological level is the environment for the self and social systems; that is, it has the most general constraints, in some sense, having the potential for all that we ever create and do. It is not an unbounded potential, for the processes of comprehension, learning, communication etc. will constrain all else. Indeed, recent interest in "explainable AI" is recognizing that automated tools are only useful and meaningful in practice if we can understand and control them.

I return to the main point that the conceptualization, personal, and practice/activity levels constitute a single system; the subsystems are themselves self-regulating but co-developing as a whole. Development occurs from the individual perspective within organized social activities (in a larger social landscape), and from the community of practice perspective as individuals experiencing and directing their own personal growth.

This perspective on cognition and design prompts many more questions: How is the quality of a design process affected by the integrity of these three levels operating as a whole? Can we observe within a design activity the self-regulation imposed by conceptualization (e.g., energy conservation in restricting conceptual change) and maintenance of the persona (e.g., holding to tribal/authoritative practices)?

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wclancey@ihmc.us
http://Bill.Clancey.name

See my web site, http://Bill.Clancey.name, for all of my publications. Contact – wclancey@ihmc.us