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DESIGN TO LEARN SCIENCE AND ART SYMMETRICALLY

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Abstract: *Design is the intersection of science and art; design is problem solving; design is the creative act that is appropriate for all the people .Within the theoretical frame of Synergetic Inter-Representation Network, a set of proposals for university education is made: experience-based learning systems to design to learn.*

Keywords: education of both cerebral hemispheres, Yui No Ron, SIRN, creativity education, interactions between science and art.

1. INTRODUCTION

My wish is to raise the next generations that move beyond taught knowledge and skills. In this paper I shall propose learning systems that promote students' change in behaviors by designing something new. This in turn leads to learning science and art symmetrically.

2. PRESENTATION AS A PRE-ADAPTATION PROCESS OF REPRESENTATION

In the Stone Age the floods of artifacts occurred all of a sudden after silent thousands of years: fishhooks, axes, spears, arrows, bows, rods, snares, ropes, nets, cave drawings, and so forth. I shall show one example of a series of creative leaps (Figure 1).

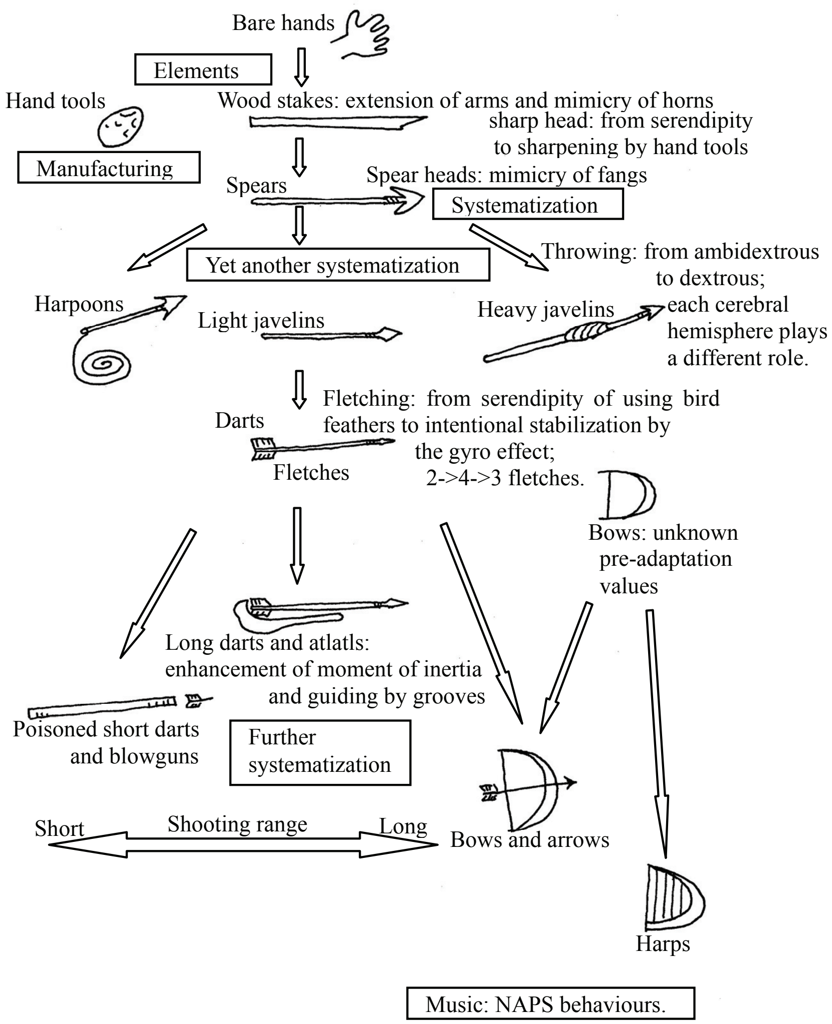

Figure 1: Creative leaps from bare hands to shooting devices and projectiles
Note: NAPS = Non-adaptive pleasure-seeking

The eve of the revolution was not silent at all actually. There seems to be developments in verbal communications among people. This is the pre-adaptation process of inventiveness, for it is an everyday design practice for people to get verbal communications with one another (Diamond, 1997).

Can we have our students experiencing the evolution of this sort? My short answer is

'Yes,' and in this context I would like to point out that presentation is one of the most important competencies for creativity in science and art. Presentation prompts students to represent new concepts.

3. CREATIVITY IN DESIGN ACTS

3.1 Creative process revisited

Koestler's 'bisociation' theory (1964) and many others unanimously insist that 'creation' is defined as the act of connecting of previously unrelated levels of experiences or frames of reference and to yield something new and appropriate to us all. Kneller (1965) extended Wallas' four-step hypothesis (1926) to the five cognitive phases: First Insight; Preparation; Incubation; Illumination; Verification (Figure 2).

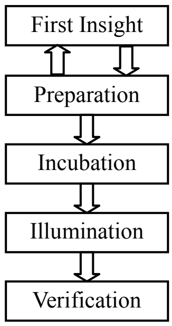

Figure 2: Five phases (Kneller, 1965)

First two phases are reciprocal. We shift our minds from defining the problem to trying to solve it, and *vise versa*, many times. In these phases once we need to indulge ourselves in abduction, divergent thinking, and associations. Then we shall revise and synthesize the solution. To do so we deduce, induce, analyze our thoughts, and synthesize the convergent solution by cause-and-effect thinking.

If we reach the solution in these phases, then we move on to the verification phase: study in the feasibility or appropriateness to the people. Otherwise we should be cool and turn away from the problem. This is the incubation phase. While we are doing something else, our thoughts still wonder about in our subconscious world to look for something useful to break through.

One morning we find ourselves close to the solution. This *eureka* moment is the illumination phase. As Wallas (1926) points out, the incubation-illumination dynamics was first mentioned by Helmholtz and later re-confirmed by Poincaré.

These five phases are observed in common in scientific and aesthetic creation.

3.2 Structure of intelligence

Intelligence has the firm structure that I call the Triangle of Sophia bridging 'knowledge,' 'skills,' and 'behavior' (Figure 3). Knowledge is explicit intelligence nourished by appropriate representations like texts, while skills are implicit intelligence taught by experiences. To move beyond taught knowledge and skills we need to change our behaviors and stabilize the renewal. Therefore behaviors are meta-cognitive skills.

Science and art are the consequence of intelligent acts, and hence the experience of creation in any levels prompts students to expand the Triangle of Sophia.

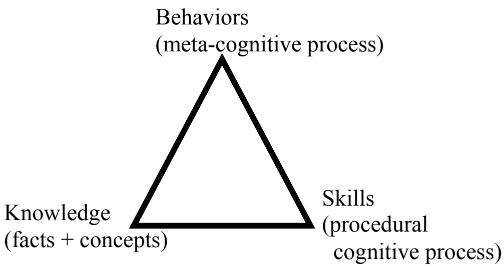

Figure 3: Triangle of Sophia

3.3 Collaboration among concentration, reflection, and presentation

When we learn something new, we concentrate the subject matter; we reflect upon it; mastery of the subject matter ends with presentation of our understanding to others. To prompt collaboration among these three competencies is the key to creativity education.

Concentration is governed by our sensors and brains. Reflection flows in our brains. Presentation is the act of our brain and actuators. This relation between competencies and our bodies is one of the bases of our new theory for intellectual acts.

4. THEORY FOR INTELLECTUAL ACTS

4.1 Yui No Ron and SIRN

Yoro (1989) coined 'Yui No Ron,' literally Brainism in contrast with Materialism, to annotate the one-to-one relationship between the world of concepts in our brains and the artifacts in real world. Haken and Portugali (1996) proposed Synergetic Inter-Representation Networks, in short SIRN (Figure 4), to explain cognitive process:

self-organization of representations; associations, thoughts and so forth are interior representations in our brains; behaviors and artifacts are exterior representations; exterior representations are the projections of interior representations. Yoro, Haken, and Portugali are insisting the same thing.

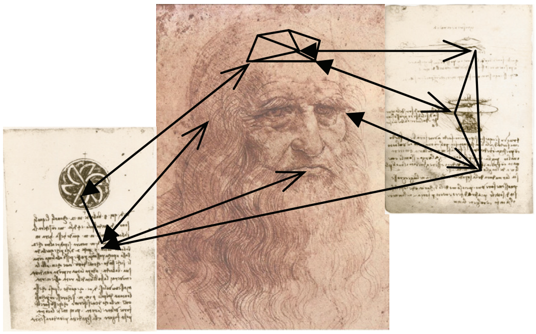

Figure 4: Inter-Representation Network

4.2 Equations of intellectual acts

To understand 'illumination' in the creative process I shall extend SIRN by introducing three-layer dynamics into internal representation: stimuli from outer environment come through 'perception layer;' thinking flows in the networks of brain 'thought space;' we act upon the surrounding environment by way of 'behavior layer' (Figure5).

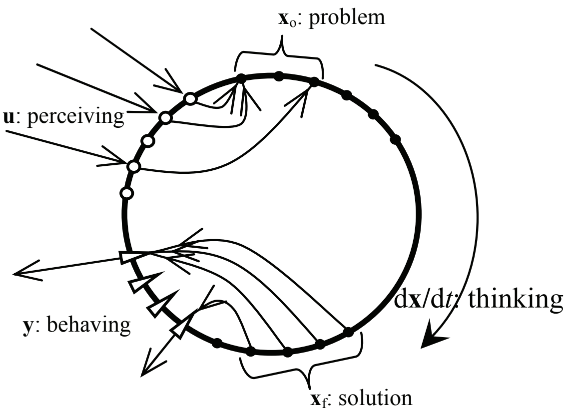

Figure 5: Brain Model

Connections between two layers are described by instantaneous dynamics:

$\mathbf{x}_0(t) = \mathbf{W}_i\mathbf{u}(t)$,

$\mathbf{y}_0(t) = \mathbf{W}_e\mathbf{x}_f(t)$, where $\mathbf{u}(t)$, $\mathbf{x}_0(t)$, $\mathbf{x}_f(t)$, and $\mathbf{y}(t)$ denote the input data-set vector in the perception layer, the initial and final state-variable vectors in the thought space, and the output data-set vector in the behavior layer, respectively; $\mathbf{W}_i$ and $\mathbf{W}_e$ designate the pattern matrix of certain, say *k*th, representation connecting the sensor layer with the processor space and the pattern matrix of the same, *k*th, representation connecting the processor space with the actuator layer, respectively.

On the other hand associations and thinking are dynamical process most simply described by

$$\mathrm{d}\mathbf{x}/\mathrm{d}t = \mathbf{G}(\mathbf{x}(t)),$$

where $\mathbf{G}$ is the nonlinear function that derives the adjacent matrix governing certain, or *k*th, representation in the neuron networks in our brain (for example Sugimoto, 2007). The representation, concepts, and ideas are attributed to the patterns of connection in the networks.

If the derived adjacent matrix is sparse, thinking becomes prone to be superficial. If the derived adjacent matrix is too dense, thinking becomes too divergent or even chaotic.
Our representation spans the complete, separable, and metric space in our mind: our concepts correspond to the entities in the real world; we can identify one concept from another; we classify concepts by a degree of resemblance.

4.3 Proposals based on the theory

Illumination is a drastic reconnection of the networks. Switching among several adjacent matrixes may lead us to a creative leap, *i.e.*, a good idea.

In this context it is a good practice for students to merge two extremely different concepts into one.

The reconnection in $\mathbf{W}_i$, $\mathbf{W}_e$, and the adjacent matrix leads us to changes in behaviors. Therefore skill-up requires reconnection in the entire networks in the sensor, processor, and actuator spaces.

To have our students experiencing the entire creative process, we need to offer a project starting from concentration to the problem finding, via reflection upon possibilities and creation of the solution, and ending with presentation of the result as a set.

5. EXPERIENCE-BASED LEARNING SYSTEMS TO DESIGN TO LEARN

I have taught university students engineering design by lectures, course works, contests and so forth. Lectures alone let students stay at operations of knowledge. Contests are prone to be objectives, but we actually want to prompt students' changes in behaviors in the end. My experience, backed up by the theory above, leads me to making most of three-month course works, *i.e.*, experience-based learning systems.

Preliminary course: studying the case of well-established design artistically or scientifically; mimicking it; applying the case to an extremely different representation.
First course: designing a product from scratch under loose constraints; in due course students need to trade off technological objectives against aesthetic aspect of the product; the presentation completes the student's mastery process.

Advanced course is a diploma project, which in Japan lasts for one year. This time students must start from finding what the problem is.
I shall show some works by students (Figure 6).

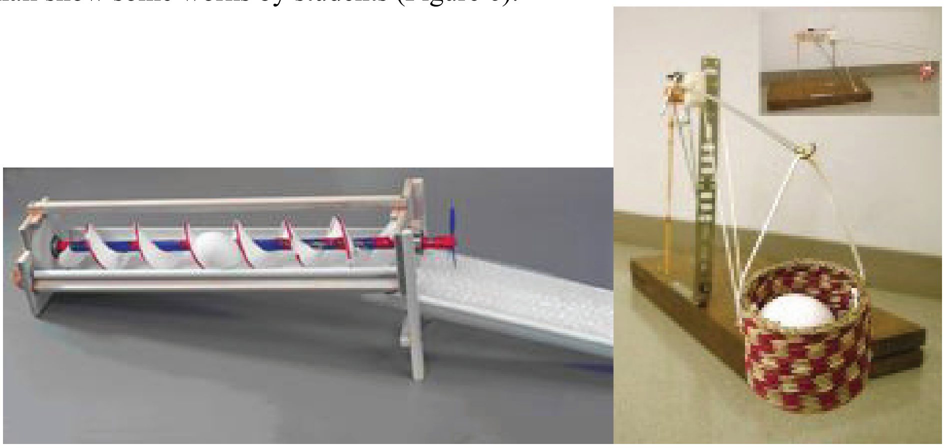

Figure 6: Rubber-powered egg movers designed by students.

6. CONCLUSION

Knowledge, skills, and behaviors constitute human intelligence. Concentration, reflection, and presentation constitute competencies for creativity. To leap creatively one requires reconnection of the intellectual networks drastically. To promote students' creativity in science and art we propose 'design to learn' by the experience-based learning systems.

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