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A TETRAGENIC FRAME FOR MODELLING UNMEDIATED KNOWLEDGE ACQUISITION*

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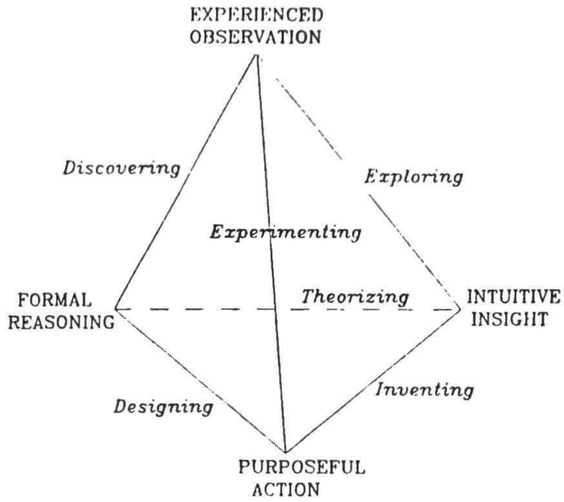
The question 'How does knowledge get into human heads?' has been asked many times before. In this paper the question is narrowed and sharpened two times. The first time, all knowledge mediated through direct contact with other human beings, as well as through various communication technologies, is exluded. Such knowledge has often been called immediate knowledge. In order not to prejudge the timing aspects of the acquisition process, it is called unmediated knowledge instead. This excludes all knowledge obtained through education as well as most learning activities. It thus restricts knowledge acquisition to processes through which people discover facts by themselves, invent their own solutions to problems and, without being told, shown or otherwise guided, figure out meanings of facts. Obviously unmediated knowledge cannot be experimented with apart from mediated knowledge without infraction of ethical codes. Unmediated knowledge acquisition is synonymous with knowledge generation. It is therefore referred to as gnomogenesis. The second sharpening of the above question comes from restricting it to gnomogenic events whose products are being reported for the first time. This restriction minimizes the probability that the knowledge had been obtained by mediation.

By singling out for study those gnomogenic events which are associated with recognized inventors, discoverers, explorers, designers, experimenters and theorizers, a more refined examination of gnomogenesis becomes possible. These six types of individuals are responsible for contributions in science, technology, art and politics. They often become singled out for special attention and, on occasion, their cognitive processes become scrutinized.

While one cannot sharply distinguish the six types of individuals, they can be associated with six cognitive processes



Model of Unmediated Knowledge Acquisition

responsible for their designations. These processes are inventing, discovering, exploring, designing, experimenting and theorizing. They are displayed, together with the four instrumentalities of gnomongenesis from which they can be derived, in the above figure.

Since the best documented cases of gnomogenic phenomena are found in the fields of science and technology, we begin the discussion with their products, the cognitive processes of discovery and invention. Discovery is a process of finding out something that was previously unknown. A classical example is a discovery of a new element in chemistry or a new particle in physics. After the discovery has been made and accepted by the scientific community the common belief includes not only belief in the existence of such an element or particle but also

*Based on material taught during the late 60's and early 70's at Stanford Universi
a graduate course entitled 'Introduction to the Heuristics of Invention and Disco

the belief that it existed before the discovery event, even though it had not been known prior to the event. It is important to note that its name is closely associated with the concept of uncovering. This implies the removal of an obstacle to observation. This obstacle is situational. The situation can be conditioned in the physical world or in the belief system the discoverer shares with his contemporaries. The discoverer removes the obstacle to perception and makes his act known. His peers confirm the new perceptions of the, now more easily accessed, object of discovery.

The act of invention differs from the act of discovery. It calls for contriving and fabricating something that had its origin in someones imagination. It becomes realized only after its idea became established in the mind of the inventor. When the act of invention is complete and the invention turns into fact, the common belief that the invention didn t exist before the act remains. While discovering deals with externalities, inventing deals with insight. It engages the more private aspects of the inventor's cognition. The idea for a wireless telegraph is a new composite with Hertz-discovered radiowaves replacing wire for the purpose of signal transmission over long distances. The idea preceded building of the device. When analyzing inventive cognition one finds introspection combined with the aim of outward demonstration of a product. Analysis of the cognitive process of discovery however indicates an outward looking aimed at an inner restructuring of situational understanding. A test, based on psycholinguistics, can verify that discovery and invention are not interchangeable. We speak of 'discovering the truth', but not of 'inventing truth'. We do say that 'a lie has been invented'. A 'discovery of a lie' could however be interpreted as a discovery of the existence of a lie, after it had been created. Thus we consider invention and discovery to be opponents in a similar sense that blue and yellow are opponents in the psychophysical space of color. This we symbolize by assigning them to two non-intersecting edges of a polyhedron.

It is necessary to exercise caution when dealing with so-called opponents. A full distinction cannot and should not be drawn between discovery and invention. While in some sense they are opposites in another sense they are not different. Here the concept of complementarity, introduced into quantum physics by Bohr for the purpose of escaping the dilemma of the particle-wave duality, can become a useful guide for the simultaneity of incompatibles. We plan to discuss this matter below.

A strong case for complementarity can be made for the second pair of gnomogenic processes: Experimenting and theorizing. That the former deals with matters external to a cognitive system, and the latter with those internal to it, need not be justified to a group of scientists. That the former swings between passive observation and active manipulation of externals and the latter between internal passive looking, literally intuiting, and internal manipulation of abstraact objects needs no demonstration to practitioners of the art of doing science.

The case for complementarity for the third pair of cognitions may be less obvious. Exploring deals with external observing of objects whose internal existence has been anticipated through internal visualization, while designing deals with internal manipulation that anticipates external manipulation of concrete objects.

Those familiar with lattice theory know that the six edges of a tetrahedron derive from forming logical unions between all of its four vertices. Equivalently the six gnomogenic functions could be derived by forming unions between four terms that suitably represent the labeled concepts at the vertices of the figure's tetrahedron. The product of two two-valued attributes will do that. The first attribute is MODE of cognition. Its value is perceiving, P, or atcualizing, A. The second is TENDANCE of cognition, signifying attendance of the environment or the self, with values E and S respectively. The tetragenic vertices of the tetrahedron become PE, AE, AS and PS in turn for top, bottom, left and right. The above simple but powerful axioms lead directly and systemically to a derivation of the four sources and six functions of unmediated knowledge acquisition. The high symmetry of this model's framework points to ease of manipulation and suggests some relationship between theories of cognitive science and those of particle physics.

What kind of technical meaning can we assign to the space bounded by the edges of the tetrahedron which is depicted in the above figure? Having labeled the edges with the six gnomogenic functions, paired into three opponents or complements, one can recognize such a space as belonging to psychophysics and psychometrics which, as Stevens points out, utilize the same scale to measure aspects of subjective responses (sensations, perceptions, judgments, etc.) and people (inventors, discoverers, etc.). Such space expresses relations between the subjective gnomogenic processes or between people assigned in accordance with the dominant function they exercise when they generate new knowledge. This space can also be utilized to chart the sequence followed by a single scientist, inventor, technologist, etc., mapping progression of his ideations after their articulation. Such graphs can display differences among such individuals and identify their strengths as well as weaknesses. They make possible recognition of dominant traits, such as observational power, reasoning power and the like.

Models similar to this tetragenic model have been used before. A pre-Socratic philosopher, Empedocles, formulated the four element model of the composition of ponderable matter. Only after 2000 years were the four elements of earth, water, air and fire replaced by the current theory of over a hundred chemical elements, called atoms. However, these are today subdivided into more primitive parts, and so on. Nevertheless the original idea, that matter is to be thought of as composed of more elemental parts, still prevails. The tetragenic model of gnomogenesis should be considered in a similar light. It accounts for the psychophysical fact that perceptions, judgements and attitudes can be decomposed into more primitive elements. Another model is Carl Jung's attitudinal model of individual types. It contains three pairs of opponents that are not equivalent. The extroverted-introverted pair is major, and the thinking-feeling and sensing-intuiting pairs are minor. Jung's theory states that one major and one minor faculty always dominate the personality of an individual. This leads to an eight-fold typology of individuals. By "feeling" Carl Jung meant the "faculty of weighing and evaluating experience", which he thought as rational as the intellectual "faculty of thinking". By "sensing" he meant the "faculty of objective presentation" and by "intuiting" "an involuntary act that lacks judgment". Our tetragenic model differs from Jung's and other models interpreting intuition. This difference leads not only to a differing interpretation of its relationship to the other gnomogenic instrumentalities of cognition, but also points toward a need to investigate different experimental phenomena within the psychology of intuition.

Let us examine a few authoritative descriptions and definitions of intuition. Quinton distinguishes between two kinds of definitions of intuition: one ordinary and the other technical. According to the ordinary one, intuitions are expressed by making rapid and accurate assertions about matters of fact in circumstances where reliance on standard procedure is ruled out. This ordinary, nontechnical, sense has been adopted by experimental psychlogists such as Hebb and Westcott when designing their experiments to test for intuitive behavior in human subjects. Among the technical ones, the most familiar definition describes intuition as the power of obtaining knowledge which cannot be acquired by either inference or observation, reason or experience. There is little question that Peirce, one of the clearest thinkers and a great philosopher of knowledge, believed that the genetic endowment of man includes, besides animal instincts and everyday "common sense", most importantly, "in the cognitive domain a sense of the plausible regarding of the workings of nature". A remarkable articulation of the nature of intuition comes from Eaton, a virtually unknown American philosopher of knowledge, who wrote during the 20's. He stated: "What intuition gives us is a residue of knowledge, left over when all that is clearly conceived or sensed in the object (the individuality of a pebble picked up on the beach) has been analyzed away". Eaton was critical of Bergson's anti-intellectualistic philosophy which equated intuition with "pure awarness" and by setting it on its own feet and thus severing "rational thought from the non-conceptual medium into which and from which it flows". Eaton saw Bergson doing violence to the cognitive act in looking "at cognition abstractly in the very effort to fasten on that which is most concrete in it". This description is reminescent of that given by Einstein, who described Bergson's theory of intuition by saying that Bergson was sawing off the tree branch on which he sat. Eaton saw cognition as "a fusion of reason, sensation and intuition".

The psychophysical tetragenic model, which we propose for cognition, is an extension of Eaton's theory of knowledge, which recognizes as the three inseparable instrumentalities of knowledge: reason, sensation and intuition. We have added a fourth instrumentality, purposeful action, and also have renamed slightly the other three. With hindsight, that uses knowledge produced recently by molecular biologists and computer scientists, we suggest that intuitive insight perceives facts about plausible workings of nature indirectly through examination of the intuiter's own physiological structure which has been constructed from genetic plans supplied by preceeding generations. This explanation provides not only a plausible hypothesis as to the origin of a priori knowledge, but also to the mechanism by which this knowledge is being constantly enhanced. It also suggests the possibility of providing intelligent machines with the power of intuition if a way can be found for the machines to gain information through inner examination of their own structure, whether hardware or software.

Experienced observation is much more than pure sensation. The whole cognitive system is attuned to integrate perceptual regularities, which map the structure of the cognizer's environment into his own, as they are transmitted through his senses and higher level cognitive processors. As pointed out by N. R. Hanson, scientific observation is inseparably loaded with theory. It should be kept in mind that the experimenter swings between observation and contrived circumstance just as the theorizer wanders between insight into his subject matter and skillful use of his reasoning methodology. By experimenter's contrived circumstance is meant an elaborate experimental set-up, loaded with instruments so that the capture of the observed phenomenon is obtained under well understood, if not completely controlled conditions. The quantum physicist has taught us that pure observation without interference from the purposeful act of measurement violates the principle of uncertainty. This means that, in general, psychophysical phenomena should be mapped only in the interior of the tetrahedron. That is a consequence of Eaton's concept of fusion of all the instrumentalities during the cognitive act. A similar explanation holds for the nature of theorizing. Swinging between intellectual reasoning and intuition is a tenet of Bergson's theory of knowledge as well

Our model describes a special theory

of cognition which may eventually provide additional leads toward a more general understanding of cognitive functions. Its interdisciplinary approach draws on special knowledge in physics, psychophysics, psychology, biology, logic, computer science and philosophy. The provisional results point toward the possibility of generalizing physic's indeterminacy principle to six principles of indeterminacy for each of the cognitive functions formed from the four gnomogenic sources.

For psychology the tetragenic model points toward a better formalization of metapsychological approaches to cognition, where psychologists study the workings of psychologists as well as other scientists. We believe that phrases containing terms like "obvious", "self-evident" and "must" are direct pointers to intuitive insights of theorizers and inventors, when they use them during reports and descriptions of their accomplishments. We think that insufficient attention is currently given to intuition by cognitive science. Using up-to-date tools, studies could follow directions indicated already by Hovland's "invention of entirely new concepts" and by Wertheimer's "productive thinking".

For the field of machine intelligence intuition points toward the design of machines which have power to gleen knowledge about the intentions of their designers by intuiton, that is examination of their own hardware and software structures and fusing that knowledge with the knowledge obtained from the other three instrumentalities, which are already part of the state-of-the-art of computers.