Hierarchies of Understanding for Human Learning

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***Abstract*—This paper describes human hierarchies-of-understanding (HoUs) as frameworks and yardsticks for (1) understanding the effects of semantic technologies on individuals and on society, (2) for designing educational courseware, (3) for designing process flows and content properties in decision support systems, and (4) for measuring the efficiency with which humans use cognitive resources, to include cognitive-cybernetic resources, such as information technology and artificial intelligence. Hierarchies of understanding are comprised of layers of understanding (data, information, knowledge, wisdom, vision). The Vision HoU informs courseware design into the age of ubiquitous artificial intelligence (U.A.I.), an age that may transform societies in turbulent ways in the 2020s. Allocation-of-understanding (AoU) is a speculative distribution of human understanding across layers of data, information, knowledge, wisdom, and vision. The Vision HoU and AoU together illustrate how semantic technologies are facilitating deep human understanding since the beginning of electronic computing, and how such trends can continue into the 2020s. This work concludes by discussing how to design suitable courseware for the age of ubiquitous A.I. (U.A.I.), so that humans play to their cognitive strengths (purpose, creativity, goal-setting, and wise decision-making) while leaving the mundane processing of data, information, and knowledge to semantic technologies and A.I.**

Keywords—Artificial Intelligence, Cognition, Complexity, Content, Context, Creativity, Cybernetics, Data, Design, Education, Goals, Information, Interface, Jobs, Knowledge, Learning, Models, Pedagogy, Semantics, Systems, Values, Vision, Wisdom.

Acronym Descriptions (extensive—keep handy!)

A.I.	Artificial Intelligence is any semantic technology that substitutes for human cognition.
AoU	Allocation of Understanding is a speculative distribution of human U across DIKWV.
D	Data is recognition of symbols of unknown extensibility. D is trivial U.
DIKWV	Data, Information, Knowledge, Wisdom, and Vision are semantic layers of HoUs.
DSM	Decision Support Model is the computer model hidden behind the computer interface.
DSS	Decision Support Systems go by many names, such as expert systems, knowledge management systems, and more. A DSS usually comprises Users, a front-end (the interface), the DSM, and a backend for DSM management. The goal of a DSS is to help Users settle into wise decisions when faced with overwhelming, yet incomplete and biased data, information, and knowledge. The Vision HoU informs DSS design.
FOM	Figure-of-Merit is a ruler of sorts used to rate the utility of individual solutions so that a wise decision (choosing the better or best solution among alternatives) can be made.
FoU	Flow of Understanding indicates the directional transfer of U from the source-of-understanding (SoU) to the target-of-understanding (ToU). The FoU can be sideways, top-down, or bottom-up (traditional pedagogy is bottom-up).
HCI	Human-Computer Interaction (sometimes Interface).
HoU[1]	Hierarchy of Understanding is a hierarchy of DI, DIK, DIKW, or DIKWV.
I	Information is U about categories of D associations. I includes words, copular sentences, constants, and independent variables. I is low-level U, static, and devoid of cause-and-effect.
K	Knowledge is U about cause-and-effect activities, such as action-verb sentences, case decisions, logic, functions, dep. variables, and individual solutions. K is mid-level U.
O	Omnicompetence is an unachievable state of perfect effectiveness in all tasks, defined by Ackoff [2] as the motivation and guide star for wisdom. Ackoff explains that without O, wisdom cannot exist, for wisdom's purpose is to strive for O. O is what separates humans from animals.
SME	Subject Matter Expert is a person recognized as an expert on one particular subject.
SoU	Source of Understanding can be the environment, a teacher, SME, A.I., HCI, DSS, or other semantic technology or entity that offers U{DIKWV} to a ToU.
ToU	Target of Understanding can be a student, novice, User of A.I., HCI, DSS, A.I. itself, or other semantic technology or entity that seeks U{DIKWV}.
U	Understanding is comprised of layers of DIKWV: U{DIKWV}.
U.A.I.	Ubiquitous Artificial Intelligence is a predicted property of near-future (the 2020s) advanced societies. Many worry about U.A.I.'s impact on the human workforce. U.A.I. is a seamless synthesis of local A.I.'s into a widespread, perhaps global, super A.I. that knows all that is known, knows the best of what is known, and can generate and validate K on its own through inference reasoning.
V	Vision is hypothetical U (conjecture) about the environment and the future. V is posited to be an evolutionary adaptation that helps humans discover and extract increasing utility from their environments.
W	Wisdom is U about the better or best solution among lesser solution alternatives. In DSMs, W is an optimized goal-function node (Wgf-node) over a system of I- and K-nodes.

[1] The phrases, hierarchy of understanding (HoU), cognitive hierarchy, and semantic hierarchy, have similar meaning in this work. Each comprises layers of DIKWV plus the context and processes that transform one layer into another.

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I. Introduction

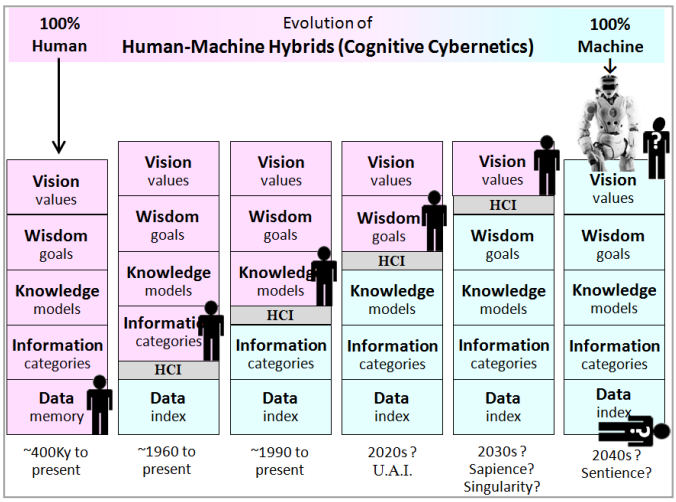

Fig.1. Evolution of human-machine hybrids.

Once A.I. (a) achieves global data (D), information (I), and Knowledge (K) awareness; (b) rationalizes for best D, I, and K (i.e., integrates and flattens the world's D-, I-, and K-bases); and (c) begins to create and validate new K by inference reasoning; then A.I. becomes ubiquitous (U.A.I.), and our human traditional bottom-up educational pedagogy becomes lethargic, anachronistic, and even obsolete when compared to what U.A.I. will be able to accomplish on its own. Already machines process D and I better than humans can by many orders of magnitude in speed, quality, and quantity. Fig.1 projects a trend in cognitive cybernetics into the 2020s, 2030s, and 2040s, a period referred to as the 'Age of U.A.I.' The goal of this work is to inform top-down courseware design that prepares humans to maintain primacy over U.A.I. through the 2020s. For all of H. sapiens's existence (leftmost col. in Fig.1), humans mentally performed each layer of understanding—U{DIKWV}—with the support of macroscopic memory and counting aids, such as by finger counting, tally sticks, paper and pencil, abacus, and slide rules. By the 1960s, electronic D-bases were becoming widespread. Today, access to D, I, and K is common, although the Internet still treats most content as D and I, for K must be extracted by the human observer. Those persons who have adequate experience and context may recognize content in a book or K-base as K, but others may view the same content as only I, no matter that the system is called a K-base. Thus, whether a decision support system (DSS) is a K-base or an I-base is relative to the observer. Such is about to change. Soon A.I. and other semantic technologies may process K as easily as computing systems process D and I today. This work assumes that such A.I. comes to fruition in the 2020s to outperform human K management. What can educators do to prepare students to maintain primacy over the machines in the coming Age of U.A.I.? This work provides partial answers to this question.

II. Hierarchies of Understanding (HoUs)

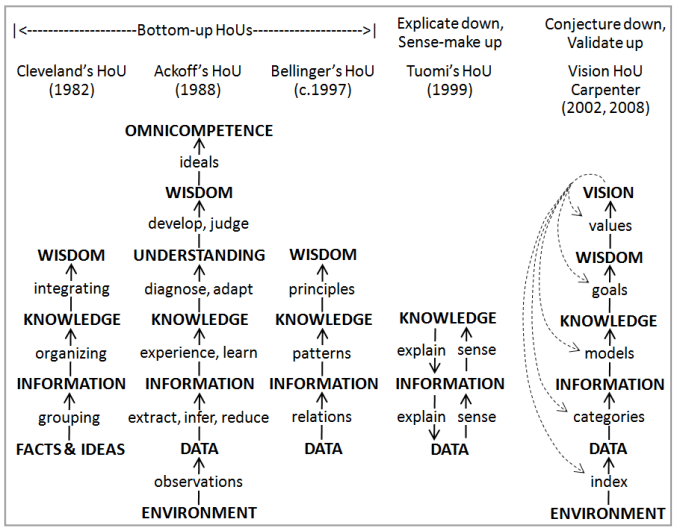

Fig.2. Progression of hierarchies of understanding (HoUs).

HoUs (Fig.2) facilitate discussion about education and courseware designs. Cleveland [1], Ackoff [2], and Bellinger [3] proposed bottom-up HoUs beginning with D. Tuomi [4] proposed a top-down/bottom-up HoU in which K, a social construct, is explained to derive I, which, in turn, is atomized to capture D. Only then can individuals "sense-make" D and I into K. Carpenter [5,6] proposed the Vision HoU in which context is conjectured downward (values, goals, models, categories, indexes), followed by context-validation in which real-world observation (content) filters upward through conjectured context to become validated U{DIKWV}. The Vision HoU informs top-down designs of educational courseware.

A. *Cleveland's 1982 HoU*

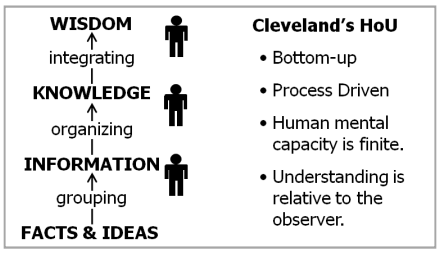

Fig.3. An interpretation of Cleveland's 1982 HoU [1].

Cleveland [1] defines a four-level, bottom-up HoU (Fig.3) comprising Facts and Ideas, I, K, and W, in which lower layers must be developed before learning processes can transform them into the next higher cognitive layer. Cleveland described his bottom layer of facts and ideas as raw materials, a kind of ore, which can be processed into something useful. Cleveland defined I as groupings of related facts and ideas, and he believed that I would become the future's "crucial resource" (p.36). In particular, Cleveland worried about near-term I-overload because advancing D-base and I-base technology

was rapidly accumulating quantities of I that just could not be analyzed and put to use by any human mind. What's the point of having more I when the quantity that you already have is beyond your capacity to analyze and to put to good use? Consequently, Cleveland focuses on warning about the impending I-overload and the need to develop means to help humans process I. Cleveland further worried that I-sharing would lead to mass layoffs, because, he believed, that I could not be effectively controlled or kept secret in a world of I-technology, and that because I can be shared so easily, that anyone can use it. A third possible social-turmoil event that Cleveland worries about is the displacement of human workers by robotics. And a fourth social-turmoil effect of the coming I-age is that of obsolescence of copyright protection. Cleveland believed that future I-systems would be so leaky, that I-control would become impossible, and that "new ways are needed to reward intellectual behavior." Cleveland ponders, "The liberal and Marxist approaches, contemporaries of the production-based society, are rendered questionable by demise [of I-control]," and that such social changes 'favor democracies.'

Cleveland analogizes K to a refiner's processing of the right kinds of ores into useful stocks of materials, such as ingots of iron. Cleveland also likens K to subject-matter expertness, processes, ways of thinking, a science, a technology, a value system, and a social system. If such analogies leave one with a foggy sense of what K truly is, well, Cleveland himself wrote, "One person's information may be another's knowledge; one person's wisdom may be another's wisecrack" (p.34). Thus, it seems that Cleveland could not explicate himself the differences between D, I, K, and W. One could infer that Cleveland was implying that such distinctions cannot be made because they are subjective to each individual, that one's U{DIKW} is relative to each observer. Cleveland even cites T.S. Eliot's famous 1934 regret: "Where is the wisdom we have lost in knowledge? / Where is the knowledge we have lost in information?" However, Eliot's adage is more a regret that people do not take the time to enjoy deeper truths about life than it is about making an argument that I, K, and W cannot be disambiguated. Nevertheless, Cleveland concludes that the differences between D, I, K, and W are subjective to each individual, a conclusion that we strongly disagree with, as explained later in the description of the Vision HoU later in this article. As for W, Cleveland defines it as an optimized interdisciplinary "system."

Cleveland posited that human mental capacity and short lifespan limit the growth of individual human K and W, but that societal K and W continue to accumulate. Consequently, back in 1982, Cleveland did not have a strong notion of the cognitive-cybernetic nature of the individual, and of humanity. For instance, Clark [8] argues in 2003 that we cannot disambiguate ourselves from our technology, that information technology is an extension of mind, that we are seamless cybernetic organisms. Thus, Clark sees no a priori limit to our cognitive ability because it expands with technology; the mind is just less and less in the head. What a difference 21 years and massive advances in semantic technologies make. Cleveland concludes by promoting education because those at the very bottom of his HoU may "find themselves unemployed."

B. Ackoff's 1988 HoU

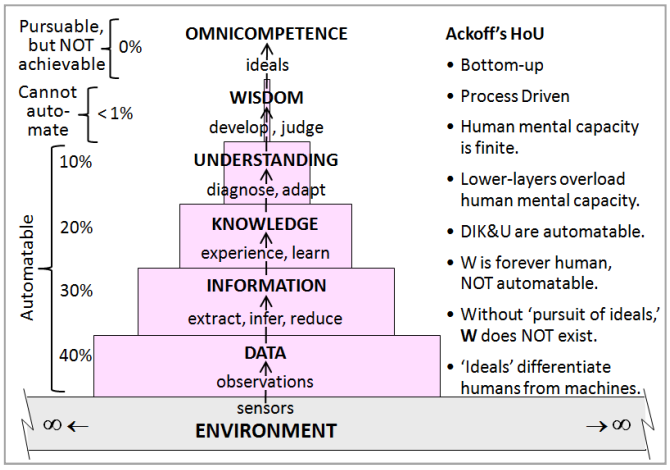

Fig.4. An interpretation of Ackoff's 1988 HoU [2].

Ackoff [2] defines a six-layer, bottom-up HoU (Fig.4) comprising D, I, K, U[2], W, and Omnicompetence. Ackoff refers to such layers as "types of content of the human mind" (p.3). Like Cleveland's HoU [1], Ackoff's is process-driven. The base layer starts by sensing something that becomes an observation, which then turns into D. Ackoff defines D as symbols that represent properties of things, events, and their environments. Ackoff states that D are useless until they are processed by analysis (extraction, inference, and reduction) into a usable form, which he calls I. I includes descriptions and answers to questions like who, what, where, when, and how many. Processes continue to build higher layers. Experience and learning transform I into K; diagnosis and adaption transform K into U. Interestingly, Ackoff seems to divide humans into two groups. In the first group, humans without an ambition to pursue ideals go no deeper than U. That is to say, such persons can only ever know D, I, K, and U, and that such is enough to prosper in human society. Furthermore, Ackoff believes that D, I, K, and U can be automated. The second group of humans not only has the ability to conceive of ideals, but also has the ambition to pursue such ideals. It is the pursuit of such ideals that enables a human to develop W. That is, W cannot exist without recognized ideals. Ackoff describes W as akin to "effectiveness" (p.4). Ackoff believes that W exists only to serve the 'pursuit of unachievable ideals,' and that pursuit of such ideals, which are encapsulated by Omnicompetence, is what differentiates "man from machine" (p.9). Ackoff believes that robots can never recognize ideals; therefore, both W and Omnicompetence are beyond the reach of automation.

Ackoff is fascinated by both Omnicompetence and W. Omnicompetence represents god-like power to achieve all ideals, and no single ideal can be achieved by humans, but only aspired to, and therefore, Omnicompetence can also never be achieved. W represents a measure of effectiveness at our ability to pursue ideals and Omnicompetence. Ackoff states

[2] Ackoff uses the word "understanding" (U) to mean a single stand-alone horizontal layer of vaguely-defined U, whereas this paper defines U as an entire vertical HoU, a stack of DIKWV.

that 'the purpose of his paper is to address whether or not it may be possible to develop a W-management system, and what would such a system comprise.'

Ackoff developed the notion of human "allocation of mental space" (p.3) in which he estimated that 40% allocates to the D-layer, 30% to the I-layer, 20% to the K-layer, 10% to the U layer, and very little to the W-layer and Omnicompetence layers. Fig.4 illustrates Ackoff's allocation of mental space as a step-pyramidal shape. Fig.4 summarizes that Ackoff believes that D, I, K, and U are automatable, that W cannot be automated, that machines can never achieve W, and Omnicompetence (and ideals) can only be pursued by humans, but never achieved.

Ackoff identified several additional interesting concepts regarding the importance for reducing I-overload, and argued for developing processes for reducing irrelevant-I in DSSs, although he did not identify particular processes. For instance, Ackoff believed that one can make better decisions with less I; that more information generally leads to poor decision-making. Perhaps it is a natural instinct to hoard all manner of things, including I, in hope that it may prove useful now or in the future. Ackoff seemed to believe that the majority of the I that managers accumulate and try to use is irrelevant-I with respect to their goals. Therefore, such additional I only serves to distract the decision-maker from good decisions. Ackoff wrote, "Very few information systems deal with this tyranny of the majority [i.e., irrelevant-I]." Notably, not much is done still today to remove such irrelevant I. Human-to-computer interfaces (HCI) attempt to filter what the user sees; however, how well does the HCI keep up with backend management of the I-system? How many Users understand the model behind their interfaces? Consider what happened at Three-Mile-Island nuclear accident. Operators had 3000 gauges and indicates to look at, yet they made the original problem far worse by misunderstanding the meanings of their overwhelming number of indicators.

Consequently, Ackoff argues that in Cleveland's I-overload age, that "filtration of irrelevant information and condensation of relevant information are two information services most sorely needed … Yet, filtration and condensation are rarely provided by computer-based MISs" Ackoff further claims that "Sstudies have shown that even good scientific writing can be reduced by two-thirds without loss of content, and that bad scientific writing can be reduced by 100% without loss of [relevant] content." Again, when it comes to MISs, how does the User know that the model behind the GUI is relevant? In school, children trust that books and teachers provide reliable, albeit, incomplete, I and K. Perhaps it would be better today to teach children to question the validity of what they are taught, and teach children how to verify on their own the validity of what they are taught.

Ackoff quotes the adage, "The better a phenomenon is understood, the fewer variables are required to explain it. (Recall $E=mc^2$). Correlatively: the less a phenomenon is understood, the more variables are required to explain it." Consequently, people do better to condense what they already know rather than acquiring more of what they don't understand. Furthermore, Ackoff makes the point that we can never know exactly what information we need until we understand completely the thing we are studying, its environment, and its interactions. Consequently, at some point, we need to make inferences, rather than collect more information.

Another salient point by Ackoff is that Users should know the model behind the DSS, how the model is applied, and the scope of its application, otherwise DSMs are inefficient, if not ineffective, because Users don't know the model behind the interface. Consider that a subject matter expert (SME) defines a system in a specification to software designers. Software designers do not understand the system, but only understand the specification. Secondly, software designers do not know the Users, who are even more removed from the system than are the software designers. Even with iterative design, usability studies, and testing, by the time the software is ready to use, it is out of date, does not accurately reflect the goals, and users and managers do not understand how the DSM is connected to the system, for even the original SME does not understand how the software designers have implemented their DSM software. Ackoff writes, "they have no criteria for determining relevance and the degree of accuracy and reliability of information required by managers, and therefore [the DSS] frequently provides them [managers] with misinformation."

On K, Ackoff describes it as that which "makes control of a system possible…All control systems have knowledge systems imbedded in them." Ackoff says, "The ability to acquire K on one's own is intelligence." And that acquiring new K is learning.

On U, the purpose seems to be to "facilitate and accelerate learning and adaptation…" That is, U enables the type of learning that leads to adapting to new situations. Ackoff believes that K and U systems will eventually be automatable, but that, today, U systems require human management. Ackoff believes that U 'focuses on efficiency…relative to one or more objectives [goals].' D, I, K, and U support efficiency to achieve a goal, whereas W supports effectiveness to achieve the value of a goal. At this point, it becomes difficult to interpret Ackoff's arguments. Intelligence{acquiring new DIKU} is related to efficiency to satisfy a goal, independent of a goal's value. Growth is learning and efficiency, whereas Development is adaptation that increases a goal's value. Thus, Growth increases DIKU whereas development increases W. Ackoff defines "development" as 'a process in which a person increases one's ability and desire to satisfy one's own needs and legitimate desires, and those of others.' Interpreting Ackoff's arguments become particularly difficult at this point in his paper, because his definitions are unclear, and possibly circular. Ackoff makes a second attempt at defining "development" by writing, "development is an increase in potential, not an increase in attainment. It has more to do with how much one can do with whatever one has than with how much one has. It is more a matter of learning than of earning, and therefore is better reflected in quality of life than in standard of living." Ackoff spends more time trying to explicate "development," introducing terms such as desire, wealth attainment, meta-ideals, omnicompetence, ethical arguments, moral arguments, internal versus external

stakeholders, religion and God, good and evil, beauty and aesthetics, conscience, relativistic approach to ethics and morality, utopia, absolutism, and satisfaction, joy, and catharsis in the pursuit of ideals.

In summary, Ackoff describes humanity as unique among machines and animals in that humans can identify and pursue ideals, ideals that can never be achieved, yet by pursuing them, we develop our effectiveness to meeting our worldly goals. Ackoff writes, "We derive at least as much satisfaction from the pursuit of solutions and objectives, as we do from attaining them. An ideal state for us, therefore, is not one in which we have everything, but one in which there is always more to be had, and in which we have ability and desire to acquire it." This is all metaphysical.

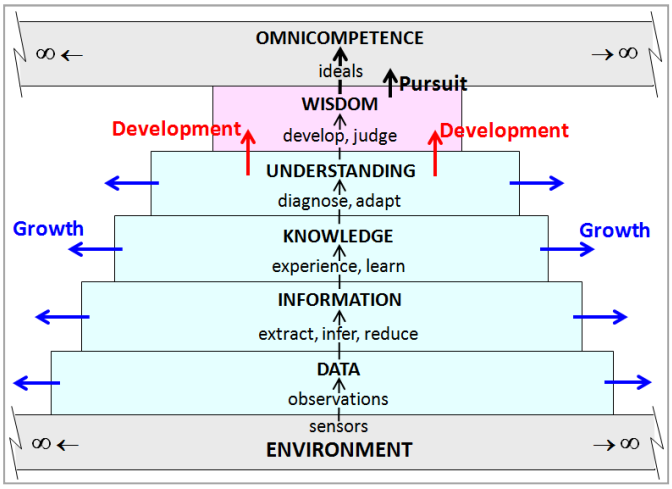

Fig.5. Summary of Ackoff's HoU: growth, development, & pursuit.

Ackoff also speculates about the lifetime of each of the semantic layers. He says that I ages relatively quickly. That seems true, if one considers words to be one type of information, then I ages from about 100 to a few 1000s of years before becoming archaic. Ackoff speculates that K has a longer lifespan, yet it too obsolesces. About U, Ackoff writes, "U has an aura of permanence about it." Ackoff says that W is permanent. 'Omnicompetence, like God, is always present,' but humans can never obtain it; we can only pursue it, and that is the highest state of humanity's achievement, the pursuit of ideals. Thus, Ackoff concludes that W-systems can never be automated—an anthropormorphic sentimentality.

Although Ackoff spends most of his paper attempting to explicate the differences between "growth," "development," and "pursuit of unachievable ideals and omnicompetence" (Fig.5), his most important contributions to the field of HoUs is that of (1) allocation of mental space, (2) filtration of irrelevant I, (3) call to develop processes to filter irrelevant I, and (4) the notion that pursuit of ideals is the most important human function. Later, the Vision HoU simplifies these notions and grounds them in natural and evolutionary theory to provide a simpler model useful for informing education and courseware design, courseware that prepares humans to use the semantic technologies and ubiquitous artificial intelligence of the 2020s.

C. Bellinger's c.1997 HoU

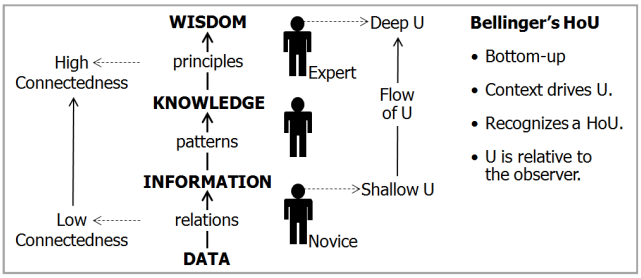

Fig.6. An interpretation of Bellinger's c.1997 HoU [3].

Bellinger [3] defines a four-layer, bottom-up HoU (Fig.5) comprising two hierarchies that work together to create U: a context hierarchy (relations, patterns, and principles) and a content hierarchy (D, I, K, and W). Understanding context is critical to promoting one layer of U into the next higher layer. Bellinger defines D as disconnected elements having no recognizable shared context with other D or content. However, once an observer recognizes relations between D and other content, then, for that observer, the relations transform D into I. Likewise, recognizing patterns among I transforms I into K, and recognizing principles among K transforms K into W. Thus, Bellinger recognizes a relativity of U, that the level of each observer's U depends upon the context recognized by each observer. An expert may perceive a system as deeply connected and may easily identify I, K, and W, but a novice may perceive said system as little connected and only recognize D and I, or only D. Bellinger may be the first to state that context enables new U and the first to recognize the cognitive hierarchy as a HoU.

Bellinger acknowledges that humans tend to apply context when none is afforded otherwise. He uses the example of the number 5, and writes, "I can immediately associate it with cardinal numbers and relate it to being greater than 4 and less than 6, whether this was implied by this particular instance or not…The implication here is that when there is no context, there is little or no meaning. So, we create context but, more often than not, that context is somewhat akin to conjecture, yet it fabricates [potential] meaning." This is a very significant observation, that humans often apply 'hypothetical context' when more obvious context is unavailable. Bellinger's simple and elegant explanation explains our human ability to discover new I, K, and W. Einstein applied all kind os conjectured context to his working K about the universe. Ultimately, he hit upon the right context on more than one occasion as experimentation later showed.

Bellinger summarizes: I relates to description, definition, or persepective (what, who, when, where), static in time and space. K comprises strategy, practice, method, or approach (how), dynamic in time and space, useful for prediction. W embodies principle, insight, moral, or archetype (why), universal in time and space, context independent, an optimization of a system. As one's U{DIKW} develops, everything is relative, and one can have partial U of the hierarchy of contexts: relations, patterns, and principles, which are the foundations of I, K, and W, respectively.

Bellinger's website [3] contains additional wisdomisms and examples not covered here, and his writing is concise and easy to understand.

D. Tuomi's 1999 Reverse-Knowledge HoU

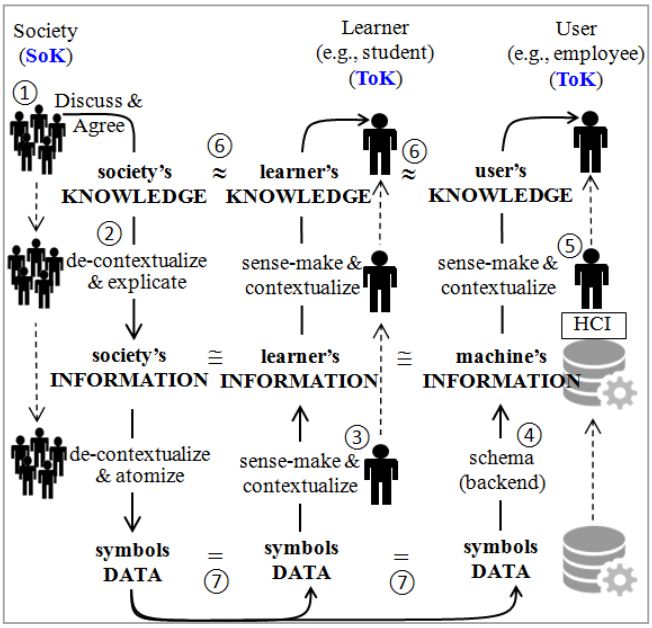

Fig.7. An interpretation of Tuomi's 1999 Reverse-Knowledge HoU [4].

Tuomi argues that our conventional thinking about bottom-up learning (D to I to K) is incomplete, or perhaps even incorrect. Tuomi [4] first defines a three-layer top-down (reverse-K to I to D) HoU (Fig.7) in which society must conceive K before society can de-contextualize and explicate such K into I, which, in turn, is de-contextualized and atomized into D. Society, through discussion, instantiates K; society is the source-of-K (SoK). Tuomi then describes two three-layer bottom-up DIK HoUs in which humans are the targets-of-K (ToK). In the first, humans learn K by making sense of society's explications. In the second, DSM designers create schema for D, which turns D into I, and then humans sense-make I into K. Human K only approximates society's K because each human has unique experience and tacit context. Tuomi's paper [4] contains additional wisdomisms and foresight not covered here.

E. Vision HoU (2002)

The Vision HoU [5,6] combines a top-down hierarchy of conjectured contexts (values, goals, models, categories, and indexes) with a bottom-up hierarchy of validated conjecture, or belief (DIKWV) (Fig.8). Thus, the Vision HoU combines elements of the top-down model of Tuomi [4] with the bottom-up models of Cleveland [1], Ackoff [2], and Bellinger [3]. V is an evolutionary adaptation that helps humans to extract increasing utility from their environments; we are born with instincts that develop into a vision-center within the mind to conjecture about the real world. In the words of Peirce [7]: "All human knowledge, up to the highest flights of science, is but the development of our inborn animal instincts" (p.477). The Environment is the source-of-U (SoU), and human vision is the target-of-U (ToU). The Vision HoU explicates the process of human learning in two phases: (1) top-down context-conjecture and (2) bottom-up context-validation.

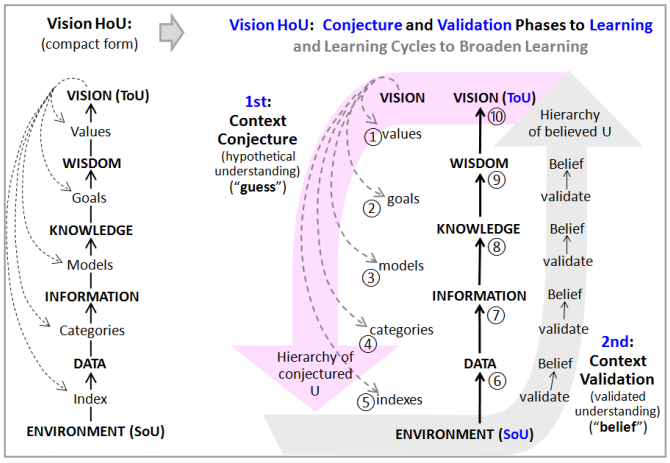

Fig.8. The compact and two-phase forms of the Vision HoU, from [5,6].

Context-conjecture phase (top-down) (Steps (1)-(5) in Fig.8). Learning begins as we use our V to conjecture a hierarchy of contexts about the real world: values (self-constraints), goals (objectives with FOMs), models (of cause-and-effect, dynamic), categories (things with labels or copular descriptions, static), and indexes (for holding data/content). Values help us to decide on and to constrain our big purposes in life. Goals support achieving our purposes. In turn, models support achieving our goals; categories of ideas support our models; and an index stores, organizes, and remembers the locations of D. Consider that many organizations guide their workforces by first creating a V statement and a core set of values; then goals are set; business models are developed; categories of ideas, taxonomies, and vocabularies are chosen; and indexes handle the D.

Context-validation phase (bottom-up) (Steps (6)-(10) in Fig.8). Once the context-conjecture phase is completed, the context-validation phase begins. Context is validated once it is shown that content (a number or other type of value), having filtered into a given layer of context, represents an accurate-enough abstraction of the environment. For example, validating the context (an index) within the D-layer requires only verifying that D can be retrieved and stored without loss or unexpected transformation, and that repeated observations of the same thing under the same conditions result in the same D. Content is validated at each layer of context (categories, models, goals, and values) by comparing the content to the environment and finding well-enough agreement. Should the context conjecturer find that the processed content does not agree well-enough with real-world observation, then the context must be re-conjectured until it meets some criteria for accuracy as validated against the real world. Once validated, conjecture turns into belief at a given layer of U{DIKWV}, and we can say that we have learned and understand more about our environment. The two-phase learning cycle broadens our U with time.

III. Competing with U.A.I. in the Workforce

A. A Century of Educating Subject Matter Experts (SMEs)

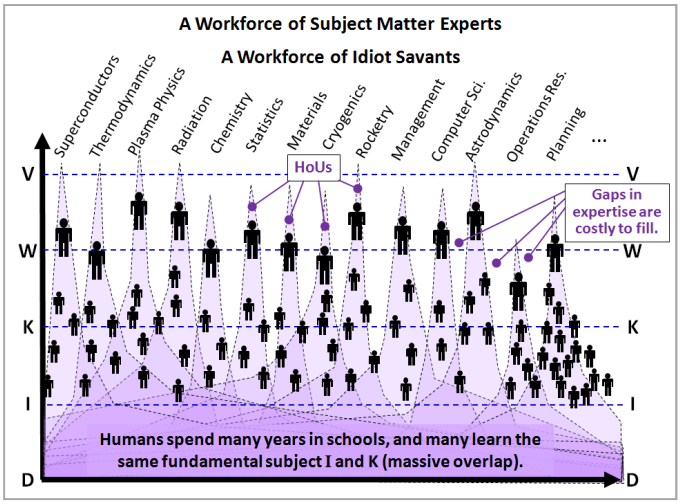

Fig.9. A culture of idiot savants?

In the last few centuries, our collective U has advanced so greatly that no longer can any one person come close to understanding it all. Consequently, we school one or more decades to become SMEs. SMEs are, effectively, idiot savants; both SME and idiot savant know one subject expertly, but too little to be competitive in any other subject in our specialist society. Modern problems are complex and interdisciplinary, and teams of expensive SMEs are required to resolve such problems. For example, take the hypothetical project of colonizing Mars. Fig.9 is an illustration of just a few of the SMEs and support staff needed to tackle such a broadly interdisciplinary project. Even if one could hire all the best SMEs in the world, other problems remain, such as the communication problem (or argument problem, or even political problem) between each group. How does the superconductor-group explain its mass requirements to the systems-architecture group that demands mass reduction—the two groups may not understand the constraints behind each other's problems and thus spend considerable time arguing before reluctantly settling on non-optimal goals and solutions. Additionally, not only is the more expert SME more expensive, but such SME is also the more powerful and influential, which may bias decision-making. Each group within a multi-group project has its own interests at heart. Each group may think it the key group; each person may feel indispensable. Therefore, management must resolve arguments between groups and individuals, mostly over resources and power within the company or project, but management rarely understands the salient details well enough to referee wisely. In contrast, U.A.I. of the mid-to-late 2020s may easily integrate and optimize all subjects. In such a future, at the DIK layers, human SMEs and idiot savants are just idiots when compared to U.A.I. Humans cannot manage trillion-node DSMs nor construct them in real-time. But U.A.I. may create interdisciplinary complex problems toward some human goal, and do so objectively, quickly, reliably, comprehensively, and at much-reduced cost as compared to the cost for human teams of SMEs and their staffs.

B. The Age of U.A.I.

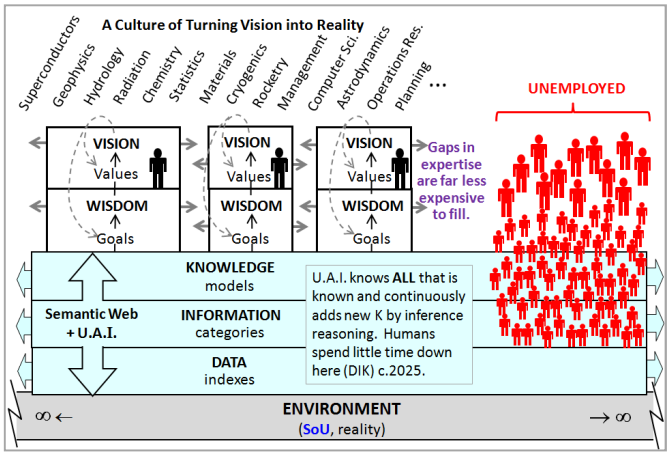

Fig.10. A new human culture of visionaries, goal-setters, decision-makers, and the unemployed.

Firstly, no matter how many SMEs a company or government can afford, U.A.I. will outperform them all by many orders of magnitude at the D-, I-, and K-layers. In such a world, humans do more envisioning, goal-setting, and decision-making than they do I- and K-learning, processing, and memorizing. In such a future, Fig.10 shows that most of the staff is newly unemployed; the company saves money; and the products are cheaper, better, and produced faster. The potential for high unemployment and related social turmoil is scary, unless U.A.I. opens enough new employment opportunities and everyone understands how to use U.A.I.; that is, people know how to formulate and pose goals and FOMs, to put U.A.I. to work. Unfortunately, our current educational system is of 19th-Century design, bottom-up, and it teaches primarily I- and K-processing, possibly because that is essentially all that kindergarten through university undergraduate education know how to measure, to grade. It is easy to grade 30 math problems in a one-hour test; however, W and V are both difficult to measure in a fair and standardized way, and such may be one reason why education pedagogies have remained bottom-up (DIK) for 160 years. Secondly, because U.A.I. is akin to a super-SME in ALL subjects, the communication and political internecine struggles for power and resources among competing departments disappear; solutions are fairly optimized across all subjects. Thirdly, U.A.I. finds such optimizations to human-proposed goals in real-time, perhaps a million or billion or trillion times faster than could be accomplished by a team of the world's best human SMEs. U.A.I. solutions may be far more reliable, accurate, unbiased, and optimized than humans could ever hope to achieve without U.A.I. The debate about whether or not the situation in Fig.10 is inexorable is a red herring because anyone in the high technology industry since 2000 has already witnessed it at some scale.

IV. What Can Be Done Now?

Many people still believe that K is an organization's highest value resource. Not so anymore! In the 2020s, the workplace may look more like that of Fig.11, in which W and

V are the highly prized layers of human U wanting additional cognitive affordances designed into HCI, DSSs, and pedagogies to prepare humans to maintain primacy over U.A.I. Albert Einstein [9], T.S.Eliot [10], Arthur C. Clarke [11], and others have recognized the fundamental importance of U{WV} over U{DIK}. We must avoid competing with U.A.I.; instead, we should use U.A.I. as a tool to enhance our natural human cognitive talents—V (purpose, creativity, and ambition) and W (goal-setting, FOM-selecting, and decision-making). Three design approaches to help educators to prepare humans for the 2020s workplace are (1) take into account that complexity, simplicity, and U are relative to the observer; and (2) educate students about the differences of D, I, K, W, and V; and (3) create course material that emphasizes V and W first, and that then helps students to discover K, I, and D second. Such approaches are described next.

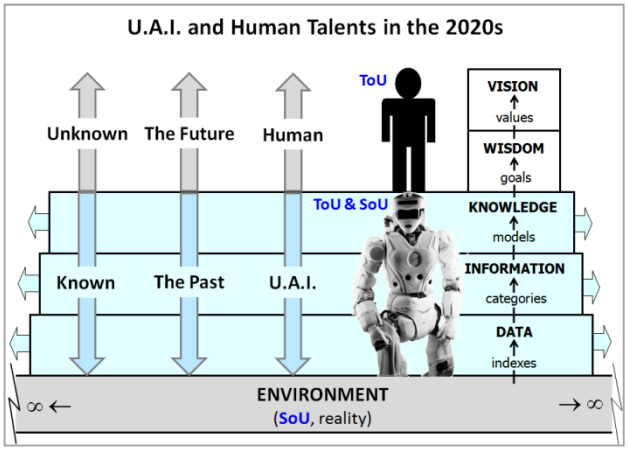

Fig.11. A Hypothetical Mid-2020s U.A.I. Workplace.

A. *Understanding (U) is Relative to the Observer*

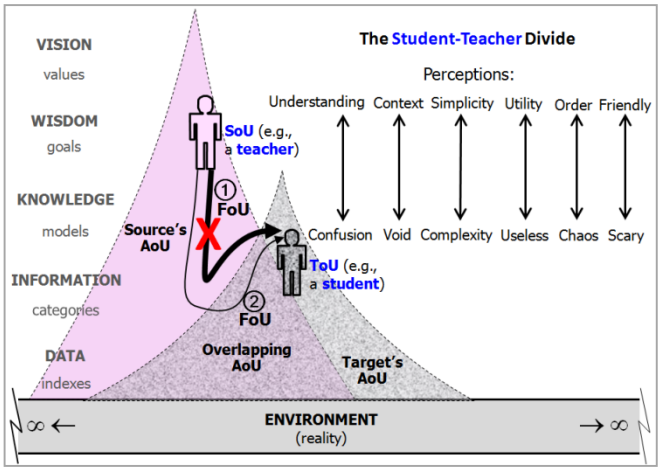

Fig.12. U is relative to the observer.

Fig.12 represents the familiar teacher-student cognitive divide caused by the wide gap in subject-matter U. From teachers' perspectives, the subject is understandable, simple, contextualized, useful, organized, and familiar. However, from students' perspectives, the subject is confusing, disconnected, complex, unusable, disordered, and scary. Thus, complexity, simplicity, and U are relative to the observer. The source-of-U (SoU) can be teachers, parents, mentors, SMEs, nature, books, DSSs, Internet, U.A.I., and anything that offers U to a target learner, the target-of-U (ToU). In Fig.12, we specify a "teacher" as the SoU and a "student" as the ToU. Thus, the flow-of-U (FoU) is from Teacher (SoU) to Student (ToU).

Two possible FoUs traverse from SoU to ToU. Firstly, through the teacher's own AoU to the student, but bypassing the student's AoU, which means that the student may not understand the teacher's explanations. Thus, FoU(1) is inefficient for two reasons: (A) the SoU uses K and I terminology that is unfamiliar to the ToU (notice that the thick line (1) avoids the student's AoU), and (B) the intended flow-RATE of U is too fast (implied by the line's thickness (1)) and overwhelms the student's cognitive capacity to process new I and K into U. Secondly, the better FoU is (2) because (A) the SoU uses K and I terminology that is understood by the ToU (notice that the thin line travels through AoU that is common to both teacher and student—see "Overlapping AoU" in Fig.12), and (B) the flow-rate of U is low enough (implied by the line's thinness (2)) that it does not overwhelm the student's cognitive ability. Therefore, HCI, DSM, and education designers should assure that teachers and students use common U to effectively communicate new U.

B. *Teach the epistemology of the semantic layers.*

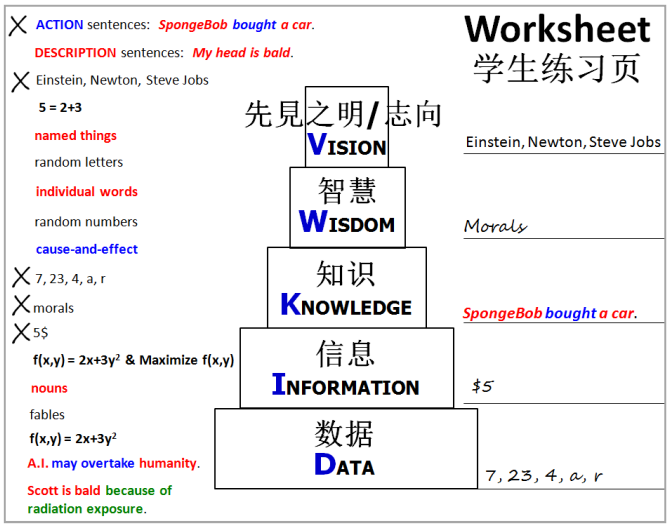

Fig.13. A Hypothetical Mid-2020s U.A.I. Workplace.

Fig.13 shows an example worksheet for teaching students the difference between the five semantic layers, D, I, K, W, and V. Our experience is that by the time of 2nd or 3rd grade, children quite easily, and quickly, comprehend the differences between these five layers. In Fig.13, five of the semantic items on the left side have X-marks, indicating that those five are already written into their proper layers on the right side of the worksheet. "7, 23, 4, a, r" are written (on the right) at the data layer, because we have no obvious use, or context for these alphanumerics. See if you can finish the worksheet.

C. Create Courseware that emphasizes V and W first.

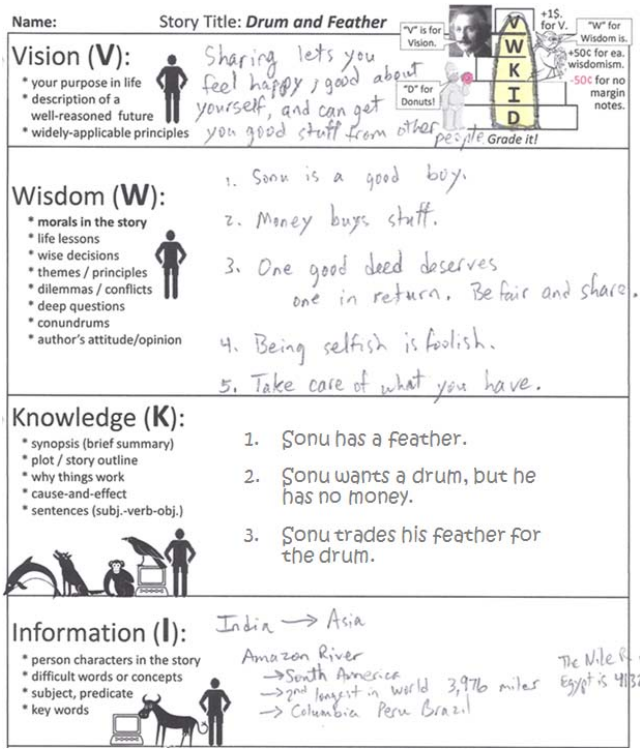

Fig.14. A Hypothetical Mid-2020s U.A.I. Workplace.

Fig.14 shows an example worksheet that emphasizes to the student the importance in reading comprehension of identifying the story's vision first, wisdom (life lessons) second, and then the plot (K) and terms (I) that require further research as needed by the student. This particular worksheet was completed by a second-grader. Students are rewarded most for identifying the story's may purpose, or vision. Second-most for the life lessons (W) embedded in the story. Consequently, whether the coursework is Math, Physics, Art, Reading Comprehension, History, and so on, the student learns to immediately look for purpose and V first, then life lessons and W. Such students learn to look at life that way as well, outside the classroom. Such students learn that computing machines are more tool than entertainer, and, it is hoped, that the student becomes the master of the machine rather than its slave.

V. Conclusion

Today, semantic technologies are already automatically processing D and I, and the traditional bottom-up education paradigm is finding its bottom automated. Our machines give us prodigious control over nearly limitless quantities of D. Likewise, soon, semantic and A.I. technologies will give us prodigious control over unimaginable quantities of I and K. As has already happened with D, so too will I and K trivialize. Human education must necessarily shift its emphasis to enhance our natural human cognitive talents—V (purpose, creativity, and ambition) and W (goal-setting, FOM-selecting, and decision-making)—while leaving the bulk of D-, I-, and K-processing to U.A.I. Our human talents involve using our imagination in practical ways to maintain our primacy over U.A.I. through the 2020s. After the 2020s, who knows!

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