Computing Literacy as a Foundation for Digital Learning

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Abstract - Computing literacy is fundamental in future learning, as human learns to have smart living in a society and environment where computing is pervasive. As we are approaching a singularity point where the intelligence of computing entities exceeds that of humans, we need to transform ourselves to have favorable relations with computing entities playing intermediary functions to environments and societies. We can achieve this objective by first mastering computing languages through which we master smart environments and smart societies.

Index Terms – Computing literacy, digital learning.

1. Introduction

We are living now in a new reality, where carbon-based biological intelligence such as human beings must now give ways to new silicon-based computational intelligence such as computers. Computing entities have been increasingly catching up with human beings in terms of intelligence. Kurzweil in his singularity theory has argued that computing intelligence will exceed that of human being by the year of 2045 [1]. Digital learning is not about how to use digital technology in enhancing traditional education anymore. It is now about learning how to coexist and find favorable relationships with computational beings. It is about creating our future, i.e., performing our own evolutionary prime roles in advancing humanity [2] in smart environments and smart societies driven by computing entities.

Spoken and written languages are a cornerstone in developing our intelligence [3]. The so-called *knowledge* is a language codification of (i) our understanding of reality and (ii) our know-how in producing values within that reality [4]. As a result, language literacy is a prerequisite for learning knowledge. Furthermore, advancing knowledge expands languages. Research expands reality languages, while learning expands literacy to cover newly expanded languages. We can master our environments, societies, and ourselves by mastering their corresponding languages.

Traditional learning concerns mostly with liberal education as well as vocational training. It focuses on human acquisitions of knowledge, skills, behaviors, or values, with objectives ranging from cultivating free thinking humans to skillful workforces. These objectives are increasingly blurred, where many academic policies mix liberating aspects with employability. Recently there are efforts to standardize educational competencies as well as institutional processes. This is driven by knowledge economy, where education has become an industry of its own. Despite these developments, today education still focuses on cultivating human according to prescribed measurable performance standards.

Such an approach has been successful, at least partially, in preparing human to live in the today's world, consisting of (i) naturally sensed reality, and (ii) pure human-thought reality. These two realities represent our external and internal worlds, respectively. However there is an increasing embodiment of *information and communication technology* (ICT) in our lives, creating smart environments and smart societies [5]. Digital reality is now considered the third reality, after the natural and human-thought reality (see Fig. 1). Here computational beings are entering our lives, creating a new smart reality. Wilber has argued that there are stages of world progressions [2], and Kurzweil singularity is one of the latest. Education must then prepare humans for this new reality.

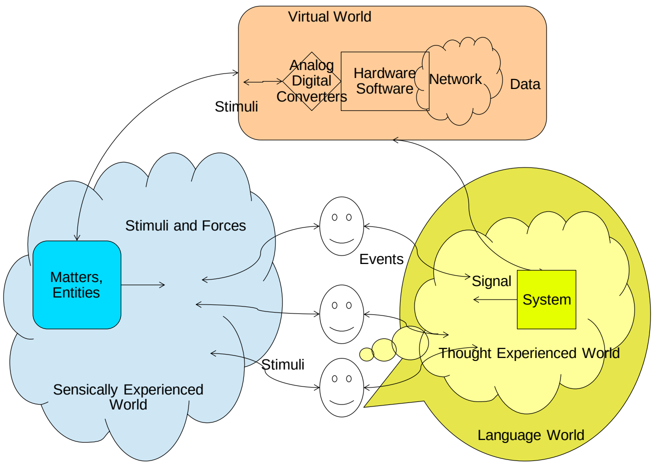

Fig. 1 Digital reality as a third reality after naturally sensed reality and pure human-thought reality.

If we want to master our new smart reality, we need to master computing languages. With computing literacy, we can understand how to live in smart environments and smart society. One way to ensure we have favorable relationships with computational beings is for us to master them. This requires our mastery of computational languages. It is then essential for our 21st century education to be based on computing literacy. We call such an education as Education 4.0. Its objective is for us to have smart living in smart environments and smart societies.

This paper is organized as follows. After this introduction, we argue in Section 2 (taken from our work in [3] with minor modifications) that our current knowledge is really based on electromagnetic facts that are coded using human languages. This knowledge has also been used to constructs electromagnetic entities and systems. In Section 3 we show that expanding electromagnetic knowledge into digital knowledge has resulted in a creation of computational beings that are highly intelligent. Here we argue that it is the invention of computing languages that give rise to intelligent computational beings out of electromagnetic constructs. Section 4 then explores computing literacy issues that are relevant with our objectives to learn smart reality and smart living. Section 5 discusses implications to computing literacy based education, or Education 4.0. Section 6 provides concluding remarks.

2. Languages for Constructing Reality

Defining a reality can be very controversial and debatable, both scientifically and philosophically [7]. It is not our intention to embark into such debates. In fact, we have chosen to follow a constructionist approach, defining reality using *languages*. This ontological approach is common in computational fields [4]. Furthermore, we will not try to develop a theory that is *true* (satisfying all scientific or philosophical sides in the debates). Instead, we are looking for a *valid* one, meaning we can use its laws to construct a virtual smart reality.

A. A Tautological Construction

It should be obvious that we have no other option in this paper but to use *languages* to define (or rather to construct) a basic reality, as also insisted by Langan [8]. Human effectively defines a simple reality using auditorial and visual language terms. The terms originally use human verbal speeches, such as combinations of spoken words. Those words are based on acoustical phones and phonemes. Later, the terms use written words, based on written symbols and letters from an alphabet.

But the language terms are not enough. Langan explains that a reality has to be *tautologically self-defined*. Using language terms, a reality is a set of sentences describing *consciousness*, as described by one of Bucke classics [1]. Inherently, a reality is *tautological* (*circular logic*): (i) it is experienced by human, (ii) it has sentences describing the experience, and (iii) both sets of experiences and sentences describe and reinforce each other. Experiences involve changes detected by senses and feelings. Sentences combine words using grammar rules satisfying syntax and semantic requirements.

In particular, a reality is constructed in our mind through changes in brain neurostructures and described using syntax propositions. Tautologically, a reality proposition is validated using senses and feeling experiences. Syntax propositions also change neurostructures, expanding our reality. Hence a reality is an interlocking of sense-supported neurostructure view of the world and its syntactical propositions in language terms. A reality is then a set of language descriptions about consciousness, that satisfy human mind abstract understanding, while are confirmable through observations and feelings, in a tautological fashion.

B. Law Codifications as Reality Constructions

Human languages describe a reality, especially by codifying (i) entities, (ii) values or forces affecting them, (iii) the entities' conditions (states) affected by values, and (iv) balancing laws relating those three. Codifications involve labeling them and creating sentences and statements relating them formally for further uses.

However we have found that the world reality can be very complex, and details are not always of the same relevance or importance to everybody. Human then develops various *sublanguages* to codify *subsets* of reality from certain corresponding perspectives, e.g., *natural, scientific*, *mathematical*, and *computer* sublanguages.

Natural or common-people languages include *stories*, *metaphors*, *theories* and *metatheories*. A story usually describes *transformations* of entities, values, and laws that *inspire* readers. To describe a reality and transformations that happen in it convincingly, a story has a language structure. For example, it is a collection of chapters, paragraphs, and sentences. This arrangement effectively changes a reader's neurostructures, expanding the mind with a newly acquired reality.

Practically all important aspects of human reality have been absorbed through stories. Examples of stories include news, folklores, fables, legends, myths, history, religious bibles, and fictions. Without stories, human cannot absorb complex reality using their senses.

For our purpose, *metaphors* are very important. A metaphor is a story that carries an old reality that has been adopted previously, evolves and expands it to create a new reality. Evolutionary natures in metaphors make them effective in introducing a new complex reality through stories. Metaphors are critically used in this paper.

A *theory* itself is a system of theorems or laws of reality. It is always described using sentences and paragraphs. A *metatheory* is an abstraction of theory. It defines criteria for a valid theory. It is the laws of theories. When human listens or reads a story or a metaphor, he or she extracts a theory embedded in the story, and use a metatheory to decide whether his/her neurostructures will absorb it in or not.

Other sublanguages create various kinds of stories to codify the world from various perspectives. Scientific languages describe physical and biological realities extensively. They describe a reality observable, experienced, or measurable by human senses. Mathematical languages emphasize on axiomatic prototypes, and apply logical inferences to construct a reality. Computer languages combine both mathematics and sciences: software is mathematical while hardware is scientific.

C. Learning and Creating a Reality

Learning is a human activity to understand changes in life reality, such that this understanding allows him/her to contribute originally toward these changes. In the process of understanding, human reconstructs the reality in his/her mind using languages. Knowledge is then a language representation of the reconstructed reality. Successful learning occurs if she/he can produce knowledge about reality and its changes. This knowledge is shared and applied to change life reality.

In practice we have four ways of understanding and creating a language-described reality: (i) deduction (*logically*), (ii) induction (*rationally*), (iii) creation (*philosophically*), and (iv) construction (*actionably*). We usually start the reality using logical deductions, the extend it using the other subsequent ways cyclically. We call this cycle as *experience* cycle for understanding and construction reality, explained as follows.

1. Using logical deduction we create an understanding of reality, by labeling things and deriving their behaviors with respect to some forces. All entities and their behaviors that are derived logically (using proofs) constitute a *logical reality*. The seed entity from which all other entities are logically derived is called *logos*.
2. Using rational inductions, one can extend the logical reality using observations. Through analogy, comparison, and metaphors, we enrich the logical reality with a *rational reality*.
3. Using creative imagination, one can create a *philosophical reality*. This reality is accepted hypothetically as long as it does not violate both logical and rational reality.
4. Using forces (efforts) and entities (resources) mobilizations, one can construct a reality as an implementation or demonstration of the philosophical reality. It is called *constructed reality*. This constructed reality further reinforces or enlarges the logical reality.

This cycle happens on language platforms. By rotating this cycle, we attempt to converge our reality to a true one.

D. Electromagnetically Constructed Reality

Naturally-sensed reality is constructed by observing fundamental particles of two kinds: (i) atomic structures and (ii) forces. What we observe are shadows or reflections of light rays, coming from photons that are responsible for electromagnetic forces. We cannot imagine humans would have any concept of space, time, matter, and energy without lights. It is considered self evident that this observable reality is electromagnetically created.

Different branches of science are simply different (sub) languages suitable to describe the same reality at different scales. As shown in Table 1, we use science to construct observable reality. However we observe and perceive reality depending on scale, as if there are different perspectives of realities. Using various electromagnetic instruments, we are now capable of observing matters or entities ranging from 10^{-15} to 10^{27} meters in sizes. For each scale we invent a different language to codify our reality. The language and its reality descriptions are called science. We invent physics for lowest scale, psychology for human scale, and astronomy for highest scale. Notice that there are two philosophical scales: zero and infinity. Here the science become formal, where the reality construction is purely human thinking.

TABLE I Electromagnetically observed reality at different scales

Diameter [m]	Entities	Branches	Science	Subjects
Infinity	Universe	Formal	Logic	Philosophy
10^{27}	Observable Universe	Space	Astronomy	Cosmology
10^{21}	Milky Way			
10^{13}	Solar System			Planetary
10^{7}	Earth	Earth	Geoscience	Climate, geology, Oceanography
10^{2}	Human	Social	Sociology	Law, Ethics, Economy
1			Psychology	Developmental Cognitive
10^{-2}		Life	Functional biology	Physiology, Medicine, Ecology
10^{-5}	Cells		Cellular Biology	Biochemistry, evolutionary biology
10^{-9}	Atoms	Physical	Chemistry	Materials, chemical reactions
10^{-15}	Particles		Physics	Particle physics, thermodynamics
0	Void	Formal	Mathematics	Computer science, statistics
			Logic	Reasoning, Philosophy

3. Intelligent Computational Entities

In additions to natural entities, our reality now includes human created entities: e.g., civil constructions, machineries, chemical products, biological entities, electrical systems and electronics, symbols, and audio-visuals. They may or may not embed electromagnetic principles or devices. Usually the smarter these entities the more it has a kind of language processing. Electromagnetic devices can be constructed to process languages, e.g., digital computers and embedded systems. It is then increasingly expected that electromagnetic devices are embedded in human created smart entities.

At the physical level we have semiconductor devices constructed using silicon (Si, with atomic number 14, a member of carbon group) substrates. Semiconductor devices include transistors used in electrical circuits to become digital gates and logic (see Table II). Logical circuits use digital gates to perform various registers, logical and arithmetical modules. Combining these modules with a controller, a program counter and an interpreter we have store-and-forward processors that accept instructions in machine languages.

After this, software becomes computing identity. Machine operating systems, assembly programming, and high level problem oriented software represent higher level of computing entities. Analogous to science subjects in Table I, we have various levels of perspectives in computing reality, including their appropriate languages.

TABLE II Six levels of computers and their corresponding languages.

Level	Language Type	Examples
5	Problem oriented	C, C++, Java, SQL, XML
4	Assembly	Assembly
3	Machine Operating System	Linux Kernel, BIOS, Lisp, NOS
2	Instruction Set Architecture	Processor Specific Machine Language
1	Microarchitecture	Archie, XScale
0	Digital Logic	VHDL, Verilog, SystemC

We can now "speak" to computer through written instructions (called programs) or literarily talk to it through speech recognition applications. Although a computer accepts any instructions, it obeys only instructions written explicitly using recognized computer languages. Hence computer literacy is essential in mastering computational entities.

Since their conceptions in almost one hundred years ago, human have put more-more instructions and programs into computing systems. As a result computing beings are increasingly intelligent, to a point that they substitute many human tasks such as data collecting, calculating, extraction knowledge, making decision, and value creations. They are even capable of creating their own: software produces software, computers produce computers. Of all criteria for intelligent beings: ability to make optimal decisions, language proficiency, and ability to multiply, computational beings satisfy them all.

We have witnessed exploding penetrations of computational beings into many important fields, including transportations, communications, control centers, military, health care, education, economy, agriculture, industry, and cultural arts. They are now indispensable in our daily life. One primary reason: these silicon beings have languages.

3. Defining Requirements of Smart Learning and Smart Living

In the future there is not much distinction between learning and living. In a larger context, human learning means following evolution imperatives to achieve human evolutionary progress. In today's context, this means preparing for productive and meaningful life. Learning should be integrated with value creations.

A. Learning for Advancing Humanity

Ken Wilber has proposed an intriguing model of humanity evolutionary progress [2]. It is based on progress in collective consciousness of humans in societies [6]. As shown in Table III, Weber's model distinguishes humans (individual or collective in a society) to progress in three tiers and nine levels. Each level is signified by unique humans' world perceptions and their corresponding strategies to create values. Humanity has since progressed from animal like instinctive-self (level 1) to sensitive self (level 6). Education means transforming humans to enter second tier.

TABLE III Nine levels of consciousness (after Weber [2]).

Tiers	Levels	World Perception	Strategy
1. First tier	1. instinctive self	Physical and biological driven. Senses and instincts	Instincts and reflexes
	2. magic/ animistic self	Full of magical threatening forces need to be appeased	Tribal rituals and animistic
	3. power self	Jungles to be conquered with forces and weapons	Dominations and conquers
	4. rule/role self	Controlled by benevolent force rewarding good deeds and punishing evils	Compliance to regulations and norms
	5. rational self	Full of opportunities and wealth	Pragmatic, scientific, initiative
	6. sensitive self	Sharing community to discover love and meaning	Consensual, flowing, help other
2. Second tier	7. integral self	A dynamic organism	Systemic, integrative
	8. holistic self	A balance of forces where human hold the key	Collective consciousness transpersonal
3. Third tier	9. unitive self	?	?

It should be noted that not all humans have reached level 6. In fact, humans are distributed at all levels at first tier, although not evenly. Hence, education also means to accelerate people at lower levels to reach level six. Furthermore, it is also understood that every person has to pass through all lower levels as a part of growing up. At an individual perspective, education transforms each person to move through those levels.

B. Human Living Needs

To design smart environments and societies, we have to decide on human needs as our primary design objectives. We always desire to live in an environment and society that triggers and fosters greatness in us. In a previous work [5], we have simplified the needs for smart living into three categories:

1. *Basic needs*. Basic living needs are those required to survive as human beings. They include availability of food, energy, clean water, housing, transportation, communications, health care, and education.
2. *Productive needs*. Productive living needs include all activities to provide wealth (e.g., financial incomes).
3. *Meaningful needs*. Meaningful living needs include socially, culturally, and spiritually valued activities. They are human needs directly related to their living aspirations.

Furthermore, we can preliminarily assign three levels of satisfaction for each need: *low*, *moderate*, and *high* levels. And those needs are reversible, meaning people can move from one level to another and go back to the original level. Using terms in our transportation metaphor, those needs are spatial.

When we say an environment 'can adapt to the changing needs of people', we have assumed a temporal aspect of reality (and needs). This is to acknowledge that needs are based on human phases of life (ranges of ages). We assign three *irreversible* ranges of ages for the purpose of designing smart environment:

1. *preparation* ages (0-22 years old). Here people prepare and orient themselves to opportunities in the world. People develop dreams and aspirations, learn the prepared ways and routes to achieve them, and practice how to travel the ways and routes.

2. *working* ages (22-45 years old). Here people journey the world by following prepared routes and perform skills they have practiced. Overtime they get closers to their dreams and aspirations.

3. *contributing* ages (45-end years old). Here people live their dreams and aspirations, create new higher-valued aspirations, develop better routes and ways, and then assist people at the previous phases to get there.

We now have three categories of needs, each with three satisfaction levels, and three phases of lives for people to have a smart living. These are requirements to be addressed in a smart environment.

C. A Smart Living Strategy: Value Creations

For that smart living, what are our options, ideas, or approaches? While admitting that options can be very subjective, for the purpose of our design, we propose smart living as *value* or *wealth creation*. Wealth in this context is a value accumulation. Values are forces capable of changing entities states. Thus, in this approach of smart living, we live our life creating and trapping values.

This approach is tautologically consistent with our idea of entities as trapped forces, and that values and forces are essentially the same. Engines use trapped forces to change entity's states adaptively and powerfully. Wealth in our definition is trapped values. Hence an engine paradigm is natural in this context.

We thus need to understand approaches in creating wealth. Following thinking from [9], wealth is created by trapping values into a compact form. It is a *compression* process. It is an *entropy reduction*. And the simplest way is through evolutionary processes.

We outline our version of the Beinhocker evolutionary process for wealth creation into a four-stroke cycle as follows.

1. External Analysis: A designer (value creator):
   a. selects an existing value entity (i.e., wealth),
   b. sees it as an instrument of an external wealth engine,
   c. understands the wealth engine configurations (i.e., the arrangements of value chains), and
   d. discovers a fitness function that makes the selected value entity fits into the wealth engine. The fitness function (or a performance measure) is usually described in terms of a ratio between beneficial values versus resource consumption values.
2. Internal Analysis: The designer:
   a. uses the selected value entity as a template,
   b. sees it as an engine,
   c. analyzes (breaks down) the engine into instruments, and
   d. understands its inner working. This also means understanding the performance (i.e., ratio of beneficial values vs. resource consumption values) of the instruments and their relations to engine performance.
3. Internal Synthesis: The designer searches for
   a. replacement instruments,
   b. new engine configurations (arrangements of instruments), or
   c. both, that are currently available in our reality (or universe). The purpose is to evolve the selected value entity into a new better one. Thus the search criteria are: (i) the new value entity is stable as an engine, and (ii) it has a higher performance according to the fitness function. In essence it is a compression process: compressing the engine to deliver more benefits for less resource consumption.
4. External Synthesis: The designer
   a. delivers a new (better performing) value entity as a result of evolving the selected one using either new instruments or a new configuration,
   b. attaches it to the wealth engine, and then
   c. has it performs better as intended.

In Ref. [5] earlier we have argued that an engineering process traps values or forces normally from three different reality views. Similarly, in the above wealth creation process, we identify three views (or even forms) of value entities: *products*, *services*, and *values*. Products are values trapped in material forms. Services are values channeled in process forms. And values are in more abstract (pure mind) wealth forms. Value creations apply those four steps for these three views of wealth. For example, successful products require (i) scientific design of the products to perform their functions, (ii) social design of organizations to produce and sell the products, and (iii) financial services to allow consumers to purchase them.

Thus we propose that the forms of wealth in our smart living should be of product-service-value system (PSV-S) [3,5]. Some will emphasize on product aspects, some on service aspects, and other directly on value aspects. But for generality, PSV-Ss should be the wealth form that we are after. Smart living is then evolving PSV-S. Smart environments are platforms to create (evolve), trade, and enjoy PSV-Ss. A smart environment itself is an instrument of a big wealth PSV-S. In fact we argue that the future we have to engineer is a smart world (a smart reality), that in essence is a super PSV-S. And it will be engineered through the evolutionary process.

5. Education 4.0

Borrowing the ideas of versioning, we propose versioning of Education as follows

- In Education 1.0 students are too early to contribute knowledge. He or she has note develop language sophistication. Teachers then use deductive learning to instill basic language, basic facts, and logical understanding in students mind. Using this approach, students rapidly acquire knowledge (i.e., reconstruct reality in his/her mind) without having to observe it.

Teachers develop and deliver bot curriculum and learning contents.

- In Education 2.0, students have basic know-how to tech him/herself. Teachers and students apply deductive and inductive learning such that students can discover themselves as well as develop their own reality. Teachers develop curriculum, while students develop contents for reality construction in their mind.
- In Education 3.0, students realize the facts that they can produce original knowledge. Teachers and students apply deductive, inductive, and creative learning. Learning process is a way to facilitate generating of original knowledge by students. Learning means creating a stimulating environment that resonates students' mind for creating new knowledge.
- In Education 4.0, students learn to change their environments and societies. Students in a community of learning apply deductive, inductive, creative, and constructive learning. Here students learn languages to master the world. Learning means developing and releasing agents of change, as well as providing fertile grounds and opportunities for students to try out their constructions.

In all cases digital technologies play significant and important roles. However it is in Education 4.0 they become essentials. Since smart environments and smart societies are driven by computing entities, computing literacy is the critical foundation.

6. Concluding Remarks

Learning is about transforming us so we can participate and contribute originally to the reality transformation. This can only be done through expanding and mastery of new languages. In today and tomorrow reality, this means learning to master the environment and society where computing beings are so prevalent and pervasive. Consequently, computing literacy is a foundation in learning.

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References

[1] R. Kurzweil, *The Singularity is Near: When Humans Transcend Biology*. Viking, 2005, 652p.

[2] K. Wilber, *A Theory of Everything: An Integral Vision fo business, Politics, Science, and Spirutality*. Boston, MA: Shambhala Publications, 2000.

[3] A.Z.R. Langi, "A Theoretical Foundation for Engineering Smart Environments Through PSV Systems", *2013 International Conference on ICT for Smart Society* (ICISS), Bandung, 13-14 June 2013

[4] J. F. Sowa, *Knowledge Representation: Logical, Philosophical, and Computational Foundations*. Pacific Grove: Brooks/Cole, 2000.

[5] A.Z.R. Langi, "Requirement Engineering of Smart Environments from a PSV System Perspective", *2013 International Conference on ICT for Smart Society* (ICISS), Bandung, 13-14 June 2013

[6] R, M. Bucke, *Cosmic Consciousness: A Study in the Evolution of the Human Min*d. Philadelphia: Innes & Sons, 1905.

[7] S. Hawking, *A Brief History of Time*. Bantam, 1998.

[8] C. M. Langan, *The Cognitive-Theoretic Model of the universe: A new kind of reality theory*. 2002. www.cmu.net.

[9] E. D. Beinhocker, T*he Origin of Wealth: Evolution, Complexity, and the Radical Remaking of Economics*. Boston: Harvard Business School Press. 2007.