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.](image)

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 $10^{-19}$ 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**

<table>
<thead>
<tr>
<th>Diameter [m]</th>
<th>Entities</th>
<th>Branches</th>
<th>Science</th>
<th>Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infinity</td>
<td>Universe</td>
<td>Formal</td>
<td>Logic</td>
<td>Philosophy</td>
</tr>
<tr>
<td>$10^{-19}$</td>
<td>Observable</td>
<td>Space</td>
<td>Astronomy</td>
<td>Cosmology</td>
</tr>
<tr>
<td>$10^{-17}$</td>
<td>Milky Way</td>
<td>Solar System</td>
<td>Planetary</td>
<td></td>
</tr>
<tr>
<td>$10^{-16}$</td>
<td>Earth</td>
<td>Earth</td>
<td>Geoscience</td>
<td>Climate, geology, Oceanography</td>
</tr>
<tr>
<td>$10^{-15}$</td>
<td>Human</td>
<td>Social</td>
<td>Sociology</td>
<td>Law, Ethics, Economy</td>
</tr>
<tr>
<td>$10^{-14}$</td>
<td>Life</td>
<td>Functional</td>
<td>Biology</td>
<td>Physiology, Medicine, Ecology</td>
</tr>
<tr>
<td>$10^{-13}$</td>
<td>Cells</td>
<td>Cellular</td>
<td>Biology</td>
<td>Biochemistry, evolutionary biology</td>
</tr>
<tr>
<td>$10^{-12}$</td>
<td>Atoms</td>
<td>Physical</td>
<td>Chemistry</td>
<td>Materials, chemical reactions</td>
</tr>
<tr>
<td>$10^{-11}$</td>
<td>Particles</td>
<td>Physics</td>
<td>Particle physics, thermodynamics</td>
<td></td>
</tr>
<tr>
<td>$0$</td>
<td>Void</td>
<td>Formal</td>
<td>Mathematic</td>
<td>Computer science, statistics</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Logic</td>
<td>Reasoning, Philosophy</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Level</th>
<th>Language Type</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Problem oriented</td>
<td>C, C++, Java, SQL, XML</td>
</tr>
<tr>
<td>4</td>
<td>Assembly</td>
<td>Assembly</td>
</tr>
<tr>
<td>3</td>
<td>Machine Operating</td>
<td>Linux Kernel, BIOS, Lisp, NOS</td>
</tr>
<tr>
<td>2</td>
<td>Instruction Set</td>
<td>Processor Specific Machine Language</td>
</tr>
<tr>
<td>1</td>
<td>Microarchitecture</td>
<td>Archie, XScale</td>
</tr>
<tr>
<td>0</td>
<td>Digital Logic</td>
<td>VHDL, Verilog, SystemC</td>
</tr>
</tbody>
</table>

We can now “speak” to computer through written instructions (called programs) or literally 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.

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.

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

<table>
<thead>
<tr>
<th>Tiers</th>
<th>Levels</th>
<th>World Perception</th>
<th>Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. First tier</td>
<td>1. instinctive self</td>
<td>Physical and biological driven. Senses and instincts</td>
<td>Instincts and reflexes</td>
</tr>
<tr>
<td>2. Second tier</td>
<td>7. integral self</td>
<td>A dynamic organism</td>
<td>Systemic, integrative</td>
</tr>
<tr>
<td>3. Third tier</td>
<td>9. unitive self</td>
<td>A balance of forces where human hold the key</td>
<td>Collective consciousness transpersonal</td>
</tr>
<tr>
<td></td>
<td>8. holistic self</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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.
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 needs of people”, we have assumed a temporal aspect of reality (and needs). We have also assumed that needs are essentially the same.  Engines use trapped forces to change 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,
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


