Knowledge-Intelligence Integrative Taxonomy

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1 - Abstract
Knowledge and Intelligence constitute the base for human cognition processes. Knowledge and Intelligence are also reciprocal since intelligent behavior requires good knowledge and good knowledge about a problem implies an intelligent behavior to solve it. Educational psychologists have thoroughly studied knowledge and intelligence concepts while discussing the teaching and learning paradigms. Knowledge was defined to be information in action or the set of skills, competencies, beliefs, and insights owned by an individual and exerted during problem solving process. Intelligence, on the other hand, is the process conditions affecting the problem solution, such as time, place, shape, suitability, appropriateness, reliability, and truthfulness. Intelligence is the general ability to learn, to acquire, and to use new knowledge.

Little, if none, has been written on building a conceptual structure for knowledge concept with major, if not all, relational connections to the human intelligence concept. The primary objective behind the development of Knowledge-Intelligence taxonomy is to create an integrated educational environment that merges between learning theories and teaching theories and guide the teacher-students communication toward a teacher-student matching learning and teaching styles.
The human cognition is a system of thinking having knowledge as input, memory, and intelligence as process tools, and intellectual capital as the primary output that represents the last stage of a three phased cognitive system: Knowledge-Intelligence-Intellectual Property.

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3 - Introduction

Between abstraction and realization stands the human mind on making decisions; sometimes life or death decisions. Use of analogies, metaphors, associations, and many other cognitive processes are brought in whenever the brain is up to making his mind. The fact that some of the brain cognitive functions are automated and others depend on the human desire to reason, makes human decisions unreliable and in need for inferences from other mental sources.

If the human brain fails to choose the right decision for solving a problem, this would be attributable to many factors of which the ignorance of the necessary clues about the problem is of major importance.

In general, if humans know their cognitive capacities and if they know what should be known in a certain situation then they would always come out with the perfect decision.

Decision making is the only human-centered concern. It shapes human’s life for the good or for the bad and depends mainly on human abilities. Of course, such a statement is somewhat unreal for it neglects the environmental influences and uncontrollable events that may alter human behavior and redirects many confirmed decisions. But considering all the humans as one single reasoning entity, and knowing in advance all the external factors, little concern may be given to small unwanted exceptions.

Restating the question differently: What would make a decision the perfect decision? The human mind itself never knows! So, is there any perfect decision at all? Or is there a better solution?

This introduction may look peculiar, but it was intended to be as such for one reason: the undecidedness of any human being. And this would lead us to conclude that there is no such a perfect human, except what God has chosen for his Mighty. Therefore, there is no such thing as perfect decision and humans will always struggle to reach the perfectness, but unfortunately, they always fail.

Despite this obscure view, the human brain is armored with powerful weapon: Intelligence. Through intelligence, great amount of problems are solved. Intelligence, still biologically unexplained, is the key to
success. But alone, intelligence is like a car engine without a fuel. Intelligence uses knowledge, all kind of knowledge, to assess situations, compare alternatives, and choose the best solution. This process is called reasoning.

This paper describes the decision making process from an intellectual perspective where the human memory both working and permanent, the cognitive processes, and the problem substance, i.e. knowledge, are all brought into the human brain during the reasoning process.

The author contribution in this respect is the development of a taxonomical representation for knowledge and intelligence concepts and their derived conceptual descendants to unify their terminological and contextual use.

4 - What is Knowledge

The term Knowledge is not new. It is as ancient as the human history. Without knowledge, the human race couldn't be able to persist. So what is Knowledge?

Some people may consider that data, information, and knowledge are different faces of a single picture and therefore fail to assess the real value of that picture. To clarify the differences of meanings between data, information, and knowledge, let us consider an example of a photo, about nature, taken by an expert photographer.

This photo can be read differently depending on the observers:

1. Some observers look at the different colors the picture hold, the number of trees, rivers, personage, and other elements that the photo may contain. Those observers are mainly interested in the different objects or data the photo holds.

2. Others may be interested in the season and weather during which the photo was taken and the kind of clothes the personage they were wearing and what kind of animals appear. Observers are looking for some useful information that gives more meaning and value to the photo.

3. The rest, and are few, are more thoughtful and want to gain new knowledge out of this photo. They look for actionable information through their observation. They apply their perceptions and commitments to
conclude the photographer values, beliefs, and integrity. They focus on the tasks used to take the photo and not only limited to the end product. Their observation is based on learning, thinking, and familiarity with the various aspects embedded in the photo. They put the photo into their framed experiences and values and assign it certain meaningful context to be semantically absorbed.

From the above example we conclude that knowledge is high in the human understanding hierarchy. But it is not at the top because knowledge is not a target by itself. Humans seek wisdom by possessing knowledge. As we mentioned before, decision making is the human-centered concern and wise people are apt to generate right decisions at the right time and in the right place.

Epistemology is the study of the nature and grounds of knowledge. Epistemology reasons that knowledge is a 'justified belief [1:8]

The following Table (41-) lists some theoretical definitions of the terms Data, Information, and Knowledge.

<table>
<thead>
<tr>
<th>Author</th>
<th>Definition/View</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data</td>
<td>«Data are unorganized and unprocessed facts. It is a set of discrete facts about events».</td>
</tr>
<tr>
<td>[3:36]</td>
<td>«Data are transaction-oriented»</td>
</tr>
<tr>
<td>[15]</td>
<td>«Data are raw facts»</td>
</tr>
<tr>
<td>[25]</td>
<td>«Data are raw facts»</td>
</tr>
<tr>
<td>[23]</td>
<td>«Data are set of discrete, objective facts»</td>
</tr>
<tr>
<td>[31]</td>
<td>«Data are discrete facts about the world, which in themselves are meaningless» (Grover &amp; Davenport, 2001)</td>
</tr>
<tr>
<td>Information</td>
<td>«Information is an aggregation of data that makes decision making easier. It is also facts and figures based on reformatted or processed data»</td>
</tr>
<tr>
<td>[3:36]</td>
<td>«Information is data drawn into patterns to reduce uncertainty. Davenport and Prusak (1998) suggest that data are objective while information «shapes the person who receives it»).</td>
</tr>
<tr>
<td>[15]</td>
<td>«Information is organized data».</td>
</tr>
<tr>
<td>[25]</td>
<td>«Information is passive in nature». (Polanyi, 1962)</td>
</tr>
<tr>
<td>References</td>
<td>Statement</td>
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<tr>
<td>------------</td>
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</tr>
<tr>
<td>[23]</td>
<td>«Information is data that «makes a difference to the receiver. It is data with added value».</td>
</tr>
<tr>
<td>[31]</td>
<td>«Information is data that has been processed or interpreted within a particular context to inform or reduce uncertainty» (Grover &amp; Davenport, 2001)</td>
</tr>
<tr>
<td><strong>Knowledge</strong></td>
<td></td>
</tr>
<tr>
<td>[10:8]</td>
<td>«Knowledge is the engine of creativity and culture and defines our humanity».</td>
</tr>
<tr>
<td>[1:8]</td>
<td>«Knowledge consists of models, which reflect the surrounding environment, resulting in targeted, simplified problem-solving and cognitive conclusions»</td>
</tr>
<tr>
<td>[5:11]</td>
<td>«Knowledge – the insights, understanding, and practical know-how that we all possess – is the fundamental resource that allows us to function intelligently. Knowledge is the principal factor that makes personal, organizational, and societal intelligent behavior possible» (Wiig, 1993:38-39).</td>
</tr>
<tr>
<td>[8:20]</td>
<td>«Knowledge consists of truth and beliefs, perspectives, concepts, judgments, expectations, methodologies and know-how.» (Wiig, 1993).</td>
</tr>
<tr>
<td>[9:217]</td>
<td>«Finding the material for learning within experience is only the first step. The next step is the progressive development of what is already experienced into a fuller and richer and also more organized form, a form that gradually approximates that in which subject matter is presented to the skilled, mature person.» («Experience and Education» (1938, p.86), John Dewey)</td>
</tr>
<tr>
<td>[3:36]</td>
<td>«Tiwana views knowledge as actionable information available in the right format, at the right time, and at the right place for decision making (2000). Knowledge is human understanding of a specialized field of interest that has been acquired through study and experience. It is based on learning, thinking, and familiarity with the problem area in a department, a division, or in the company as a whole.»</td>
</tr>
</tbody>
</table>
«Knowledge is a fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information. It originates and is applied in the minds of knowers. In organizations, it often becomes embedded not only in the documents and repositories but also in the organizational routines, processes, practices, and norms.» (Davenport & Prusak, 1998).

«Knowledge is neither a fact nor a message acting upon the receiver. It is a potent stew of experiences, values, context information, and expert insight that resides within the individual.» Davenport and Prusak (1998)

«Knowledge is information that has been understood, interpreted, and validated in the context of application.»

«Knowledge is generated by putting information in a social context.»

«Once knowing is no longer understood as the search for an iconic representation of ontological reality, but, instead, as a search for fitting ways of behaving and thinking, the traditional problem disappears. Knowledge can now be seen as something that the organism builds up in the attempt to order the as such amorphous flow of experience. Von Glasersfeld (1984)»

«Knowledge is organized collection of facts, rules, and heuristics plus the how and when to apply them.»

«Knowledge is constructed through the interplay between an individual's knowledge and judgment in a particular context.»

«Knowledge is dynamic and active resources, residing in peoples' heads» (Polanyi, 1962).

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<td>[12]</td>
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<td>[18]</td>
<td>«Knowledge is generated by putting information in a social context.»</td>
</tr>
<tr>
<td>[21]</td>
<td>«Once knowing is no longer understood as the search for an iconic representation of ontological reality, but, instead, as a search for fitting ways of behaving and thinking, the traditional problem disappears. Knowledge can now be seen as something that the organism builds up in the attempt to order the as such amorphous flow of experience. Von Glasersfeld (1984)»</td>
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<tr>
<td>[27]</td>
<td>«Knowledge is dynamic and active resources, residing in peoples' heads» (Polanyi, 1962).</td>
</tr>
</tbody>
</table>

Table 4.1: Data, Information, and Knowledge

This research is knowledge centered. It builds upon this unique and essential substance. Therefore, it necessitates a clear definition for the word knowledge and a mapped view of its sources, resources, processes, functions, and outcomes.

As mentioned from the definitions above, knowledge is not physical.
It differs from data and information in the fact that it has a human considerations and not simply human manipulation. Knowledge reflects human behavior, beliefs, values, insights, perceptions, judgment, expertise, culture, understanding, and many other human capacities, abilities, and cognitive powers.

Knowledge is an effective measurement of the humanity civilization level. The more we know (what, how, when, and why) the more we value ourselves closer to the wisdom level.

Also knowledge is an important prerequisite of creativity. Creativity is defined as the connectedness between two different knowledge domains. The better domain knowledge is cultivated, the more creative insights could be harnessed. Sallis and Jones stated that «knowledge is at the heart of human civilization. It is the engine of creativity and culture and defines out humanity» [10:8].

Figure 41- depicts a relatively detailed model for the knowledge system (or knowledge taxonomy); so far called system for the input-process-output features it involves. The model views knowledge from different perspectives:

1. static vs. dynamic
2. input vs. output
3. process vs. function

The knowledge taxonomy, developed solely by the author, can be considered as a fundamental base for Knowledge Management for it maps individual as well as organizational knowledge dimensions and institutes for its proper manipulation and use. The terminology defined in this taxonomy is directly used throughout this thesis.

The scope of this research is beyond going through all the specific aspects involving knowledge, however general considerations are described in the sections that follow.
Figure 4.1: Knowledge System Model (Knowledge Taxonomy)
4.1 Knowledge Components

Knowledge components describe the bases on which knowledge is constructed. Learning and Thinking, for example, are indispensable for knowledge creation during the educational process. Familiarity with the domain problem, Skills, and Common Sense reinforce the knowledge creation process at the individual level and provide a framework for evaluation and assessment. Values, Perceptions, and Expert Insights are the humanistic dimension given to knowledge. They represent beliefs and commitments the knower may have toward what he/she knows [3:36].

John Mingers, in [31], distinguished four generic forms of knowledge based on (i) the object of knowledge, (ii) source, (iii) form, and (iv) truthfulness. In that context, knowledge components can be grouped into what Mingers considered as different ways of justifying their claim to truth:

1. Propositional: know that.
2. Experiential: know something.
3. Performance: know how.
4. Epistemological: know why.

4.2 Knowledge Sources

According to [9:217], there are five approaches through which knowledge is acquired:

1. Reasoning: the use of cognitive rules to take some actions.
2. Divine Revelation: in what concerns God's knowledge given to his Prophets and Messengers.
3. Intuition: is a set of perceptions and insights residing in the head of the expert.
4. Empiricism: through experiences, rehearsals, and practices guided by experts.
5. Authority: trainers, teachers, textbooks, and others form an
authoritative and trustful source of knowledge.

4.3 Knowledge Types

Knowledge is represented in different forms depending on factors such as:

1. Situation.
2. Case problem.
3. Sender and Receiver expertise.
4. Technology used.

The three major types representing the body of knowledge are the following:

1. Facts: a fact is a declaration of some aspect of truth about a subject matter or domain. Facts are two dimensional:
   
   a. Declarative Knowledge: knowing-what, declared through lectures, training sessions, reading, writing, speaking, and so on. Declarative facts are the «skills, strategies, and resources needed to perform a task» [7:260]. They are also called «awareness knowledge or routine knowledge» [3:42]. Declarative knowledge is academic knowledge involving theorems, propositions, assertions, and laws [15].

   b. Procedural Knowledge: knowing-how, must be demonstrated through a set of sequential steps showing how to use strategies. «It is often the driving force behind the learning skill» [4:13]. It is the mechanics of conforming to the theories' requirements in a particular situation [20].

2. Procedural Rules: a procedural rule is a series of relations describing a process or routine. «They are represented as condition-action rules sometimes called productions» [7:238].

   a. Conditional Rules: knowing-when and -why to apply the declarative and procedural facts or strategies.

3. Heuristic Rules: a heuristic rule is a rule of thumb based on years of experience.
a. Episodic Rules: they are rules based on incidents, events, or experiential information tied to a particular place and time.

b. Semantic Rules: they are rules for meanings. They include propositions, major concepts, domain specific vocabularies, formal descriptions of terms and their relationships. Semantic rules «are highly organized chunked knowledge that resides in long term memory» [3:42].

An important characteristic featuring experts is that «much of their declarative knowledge has become proceduralized, that is incorporated into routines and can be applied automatically without making many demands on working memory» [7:269]. Experts know what action that best fits the condition-action schema stored in their heads.

### 4.4 Knowledge Categories

Knowledge is not physical in all its types. Knowledge is complex and hard to express for it embeds the knower humanitarian aspects besides its representation of the world facts, and for it is mostly created through action. Knowledge is difficult to express and requires lengthy statements to materialize into a simple and comprehensible form. In that concern, knowledge has been categorized into Tacit and Explicit. Authors have written much to describe these two categories. Table (42-) depicts authors' views about tacit and explicit knowledge.

<table>
<thead>
<tr>
<th>Author</th>
<th>Definition/View</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explicit Knowledge</td>
<td>«Captured in some tangible form – Novices are apt to easily verbalize – Ability to disseminate – Ability to teach – Ability to organize, to systematize – Transfer of knowledge via products.»</td>
</tr>
<tr>
<td>[5:20]</td>
<td>«Explicit knowledge is formal and systematic.»</td>
</tr>
<tr>
<td>[2:21]</td>
<td>«Because explicit knowledge is the knowledge that can be most easily articulated and transmitted, it is sometimes called codified or declarative knowledge. Explicit knowledge is: declarative (know that), codified, objective, tangible, and easily communicated and transferred.»</td>
</tr>
<tr>
<td>[4:10]</td>
<td>«Explicit knowledge is codified and digitized.»</td>
</tr>
<tr>
<td>[3:15]</td>
<td>«Explicit knowledge is only ever a limited representation of human knowledge.»</td>
</tr>
</tbody>
</table>
«Explicit knowledge transfer consequences can be measured through patents, licenses, and publications.»

«Explicit knowledge (know what), also called declarative or academic knowledge, is the knowledge we are familiar with as facts, theorems, propositions and laws.»

«Explicit Knowledge: Tangible, Systematic, Ease of transfer.»

<table>
<thead>
<tr>
<th>Tacit Knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>«Difficult to articulate – Reside within the heads of knowers – Ability to adapt – Expertise – Ability to collaborate – Coaching and mentoring»</td>
</tr>
<tr>
<td>«Tacit knowledge is highly personal and difficult to communicate to others. Or in the words of the philosopher Michael Polanyi: ‘We can know more than we can tell’. It consists of mental models, beliefs, and perspectives so ingrained that we take them for granted, and therefore cannot easily articulate them.»</td>
</tr>
<tr>
<td>«Tacit Knowledge is the sum total of the actions, experiences, ideals, values, and emotions of an individual. It is often context specific and can only be expressed and communicated through metaphor and by analogy. Tacit knowledge is: knowing how (procedural), socially constructed, technical and cognitive, the folklore of the organization, inside people’s heads, the mastery of a skill, values, insights, hunches, prejudices, feelings, images, symbols, beliefs, chaotic, difficult to codify and store, difficult to communicate and share, and rich source of experience and learning.»</td>
</tr>
</tbody>
</table>

Tacit knowledge is intuition, values, and beliefs. It is embedded in the human mind through experience and jobs. It is best communicated personally through dialogue and scenarios with use of metaphors.

«Knowledge is considered to be largely tacit or rooted in tacit knowledge.»

«Tacit knowledge transfer from the research center can occur through cooperative education programs and from hiring of recent graduates… Tacit Knowledge transfer embodies non-patented or non-licensed product and process technologies.”
Tacit knowledge (know why) is more personal, context specific, and practice based (Nonaka & Takeuchi 1995). It is often difficult to formalize and articulate and often must be inferred from actions or statements.

Tacit knowledge: contextual, mental processes, difficult to transfer.

<table>
<thead>
<tr>
<th>Table 4.2: Tacit vs. Explicit Knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>To resume, explicit knowledge is declarative, tangible, and can be easily transmitted via teaching, documentaries, and patents. Explicit knowledge is structured and codified building blocks. It takes the form of manuals, policies, procedures, databases, and reports.</td>
</tr>
<tr>
<td>Whereas tacit knowledge resides in the knower's head, and is difficult to communicate for it is highly personal. Tacit knowledge is «job specific, contextual, difficult to articulate and poorly documented but highly operational in the minds of the possessor (Kidwell, Vander Linde, and Johnson, 2000)» [1:9]. Tacit knowledge is difficult to formalize, capture, communicate, and share.</td>
</tr>
<tr>
<td>The idea behind categorizing knowledge into tacit and explicit resides on the fact that knowledge is becoming an asset that determines the wealth of the organizations. Therefore, nurturing organizational knowledge is strategic and requires top management focus on both types of knowledge especially tacit for it is personal, difficult to communicate, and always taken for granted.</td>
</tr>
</tbody>
</table>

4.5 Metacognitive Knowledge

Your knowledge about the world is one thing, and your knowledge about what you know about the world is another thing. In other words, metacognitive knowledge is knowledge about knowledge. It is knowing what you know, knowing how to think about it, knowing how to learn from it, and what resources are necessary to increase your knowledge.

Anita Woolfolk, [7:260], has defined the metacognitive knowledge as «people's awareness of their own cognitive machinery and how it works. It is cognition about cognition, or knowledge about knowing.»

During the decision making process, people make use of some strategies to analyze the problem case, look for alternatives, and select, implement,
and test the best one. The metacognitive knowledge is concerned with the thinking methods during the decision making:

1. How to reason about the problem issue.
2. How to comprehend it.
3. How to solve it.
4. How to learn from it.

The metacognitive knowledge calls for the declarative knowledge about the skills and thinking strategies that the problem solver has, for the procedural knowledge that describes how to use these strategies, and finally for the conditional knowledge to decide on when and why to apply these thinking strategies.

Anita Woolfolk considered the metacognitive knowledge as thinking and learning regulator that requires the following three skills:

1. Planning: deciding on the time to start, resources to use, and strategy to follow in the thinking process.
2. Monitoring: examining the thinking success or failure and suggesting new strategies.
3. Evaluation: assessing the whole thinking process, learning from it, and making judgments and suggestions for future cognitive practices.

4.6 Knowledge Management Functions

In an attempt to posit knowledge as a cultural evolution, Francisco J. Ricardo, in [33], considered Knowledge Management as a semi-paradigmatic discipline that follows Feudal and industrial cultures and precedes the creative culture. Both the organizational and cultural aspects of Knowledge Management focus on more sharing methodologies to improve customers' relationships and work effectiveness with terms like «distributed mind (Fisher & Fisher 1997), the collaborative enterprise (Skyrme, 1999), knowledge communities (Botkin, 1999), virtual enterprising (Savage, 1996).» The distributive involvement of knowledge culture in all the organizational internal and external processes imposes a multidisciplinary expertise in Knowledge Management functions.
Daniel G. Andriessen, [32], argued that knowledge is differently conceptualized depending on the “unconscious choice of metaphor” which would influence the way we reason, see, and understand various abstract concepts. For that purpose, he developed a Knowledge Management Metaphor Analysis Scoring Form that categorizes Knowledge Management functions depending on the metaphorical conditions.

The fact that the disciplinary expertise governs people set of metaphors they formally or informally use to externalize their knowledge leads us to adopt the multidisciplinary factors: Human, Organizational, and Intellectual, to categorize the various metaphorical Knowledge Management functions.

5 - What is Intelligence

Knowledge constitutes the only substance manufactured in the brain. Intelligence governs the manufacturing process and provides it with necessary accuracy, reliability, speed, and integrity. So what is intelligence?

Table (51-) presents few definitions for both human and artificial intelligences. There is a tight correlation between both fields for the main reason that artificial intelligence research has contributed enormously to the understanding of the human intelligence itself. The artificial intelligence has brought new concepts and structure about thinking [3:51].

Intelligence is that immaterialized power that is sought to be possessed by all: individuals, organizations, and systems.

At the individual level, people compete to prove their superiority in cognitive based fields such in schools, universities, training, research, and so on. They enthusiastically show their cognitive skills by learning and applying what they have learned. Howard Gardner suggested the multiple intelligences theory which entails a large proportion of intelligent people but in different areas [9:165].

At the organizational level, intelligence is becoming a corner stone for almost all organizational constituents. This fact is driven by the recent Learning Organization trend which suggests that «[a] learning
organization is an organization skilled at creating, acquiring, and transferring knowledge, and at modifying its behavior to reflect new knowledge and insights»[4:47].

At the system level, artificial intelligence works closely with the individual and organizational intelligences through expert systems and learning machines. The artificial intelligence is multidisciplinary which provides a base for challenging, integrative, and interoperative projects.

<table>
<thead>
<tr>
<th>Author</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Human Intelligence</td>
<td></td>
</tr>
<tr>
<td>[9:165]</td>
<td>«Intelligence is the general ability to learn, to acquire, and to use new knowledge. Gardner suggested that there were at least seven human intelligences: Logical – Mathematical, Linguistic, Musical, Spatial, Bodily – Kinesthetic, Intrapersonal, Interpersonal, Naturalist»</td>
</tr>
<tr>
<td>[3:35]</td>
<td>«Intelligence refers to the capacity to acquire and apply knowledge. Ability to understand and use language is another attribute of intelligence.»</td>
</tr>
<tr>
<td>[4:275]</td>
<td>«James G. March thinks that «Organizations pursue intelligence. In that pursuit, they process information, formulate plans and aspirations, interpret environments, generate strategies and decisions, monitor experiences and learn from them, and imitate others as they do the same.»</td>
</tr>
</tbody>
</table>

| Artificial Intelligence |
| [6:38] | «Artificial Intelligence was coined in 1956… A system is rational if it does the «right thing», given what it knows.» |
| [3:36] | «Artificial intelligence […] studies the cognition of computer-based intelligent systems» |
| [29] | «As concepts are the most basic units of thought, it is not surprising that they became important building blocks in Artificial Intelligence research. Their appearance is prevailing in Knowledge Representation (e. g., in semantic networks, conceptual graphs, description logics), but they also appear for instance in Machine Learning (e. g., in conceptual clustering, concept learning).» |
Nowadays, an Artificial Intelligence (AI) technology which emerged in the late eighties as a means for sharing knowledge between knowledge based systems, ontologies, is advocated as the preferable solution for enabling interoperability. Their applications vary across a wide range of fields, including Web-based Educational Systems (WBES).

Software design, or software engineering, is the discipline concerned with the construction of software that is efficient, reliable, robust, and easy to maintain. There is still an area that is unexplored: bringing into the design process explicit knowledge regarding the domain on which the system to be developed will operate. The study and modeling of that knowledge is a core theme in artificial intelligence research.

<table>
<thead>
<tr>
<th>Table 5.1: Intelligence vs. Artificial Intelligence</th>
</tr>
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<tbody>
<tr>
<td>The Intelligence system model is briefly described in the following sections (see Figure 51-).</td>
</tr>
</tbody>
</table>

**5.1 Definitions**

In general, Intelligence is defined from three perspectives:

1. Linguistic perspective: the ability to understand and use languages. Language is the key to learn, understand, and explain knowledge.

2. Internal perspective: the ability to build, improve, and transform acquired knowledge. It is a mind power that characterizes creativity and promotes innovation.

3. External perspective: the capacity to apply and acquire knowledge. It depends on both personal and external factors such as the place, time, and methods used to employ knowledge.

**5.2 Cognition**

Cognition is an act of mind during which people use a set of reasoning rules and procedures for the purpose of designing and implementing an action, performing a certain behavior, making decisions, and solving problems. Chris Argyris stated that cognition is «how to reason about [...] behavior.» While Dorothy Leonard & Suzan Straus mentioned that cognition is an approach to «perceiving and assimilating data, making decisions, solving problems, and relating to other people» [2:81]. In
addition, they claimed that cognition is a personal preference that may change according to situations.

According to Elias M. Awad & Hassan M. Ghaziri, researchers tackled cognition from two perspectives [3]:

1. Psychological perspective: one that identifies cognitive processes and structures required to accomplish effectively and efficiently a specified task.

2. Scientific perspective: studies human intelligence using experimental psychology to build a computer-based intelligent system that uses assimilated human cognitive processes.

5.3 Types
Howard Gardner, in his book «Frames of Mind: The Theory of Multiple Intelligences (1983, 1993a, p.8)», [9:165], advocates that human intelligence is not solely logical or mathematical that helps the individual take a decision or behave in a certain way or another.

Gardner attributed various human competencies to a context specific intelligence and by that he suggested at least ten human intelligences:

1. Logical and Mathematical intelligence.

2. Verbal and Linguistic intelligence.


6. Intrapersonal intelligence.

7. Interpersonal (social) intelligence.

8. Naturalistic intelligence (recognition of the environment and the natural world).

9. Existential intelligence (concern with the human condition).

10. Spiritual intelligence.
The theory of multiple intelligences put forward by Gardner has had considerable influence in education and has important consequences for organizational learning. Unfortunately, the Information and Communication Technologies (ICT) is still short of putting the various human intellectual competencies into work.

The current research tackles directly this issue by suggesting an integrated ontological approach which maps all human life cycle starting from the educational stage up to the working stage and dealing with a multitude of human functions: learning, researches, activities, work, and so on. This integrated approach is easily extendable to cover remaining human functions including: living, hobbies, sports, spiritual activities, and many others.
Figure 5.1: Intelligence System Model (Intelligence Taxonomy)
5.4 Components

5.4.1 Learning

When people learn, their knowledge is modified reflecting an observable change in behavior and an unobservable change in the permanent memory of the mind. Behavioral change, however, is limited to social constraints and environment expectations.

David Garvin, in [2:47], defined learning to be "the process of improving actions through better knowledge and understanding." Garvin considered, in the learning process, factors that change potential behaviors such as information processing, errors detection and correction, sharing (insights, knowledge, and mental models), and past experience.

Anita Woolfolk, in [7:238], and Forrest Parkay et al., in [9:165], considered learning to be the «result of our attempts to make sense of the world» [7:238]. Their view of learning differentiates between learning by thinking about situations (knowledge, expectations) and learning by changing behaviors (interactions, environment). Anita suggested two views of learning:

1. Cognitive view: also called collaborative, where knowledge is the learned material through acquisition, depth on understanding, and feedback. Cognitive theories are based on «personal meaning, generalizations, principles, advance organizers, discovery learning, coding» [9:165].

2. Behavioral view: also called objectivist, where new behaviors are directly learned through observation and stimulus response associations [22].

David Garvin, and Forrest Parkay et al., anticipated a third view for learning that they called Performance Improvement view (or construction view). Constructivist view of learning emphasizes the construction of a new meaning for an already known knowledge. It involves active learner participation and not just mere passive gathering of knowledge.

Hoadley and Kilner, in [17], argued that communities are excellent settings for modern learning theories. They distinguished four major
learning theories:
1. Behaviorist learning: results in changing learner behavior.
2. Developmental learning: results from interaction with the world.
4. Sociocultural learning: results in proper social practices.

Lim and Weber, in [16], presented five learning theories having links with the practicality of doing:
3. Experiential learning: addresses the specific needs of the learners in a self directed and self-controlled learning experience.
4. Constructivist learning: learning by creating knowledge from using what is known to find sense of experiences.
5. Cognitive Information Processing: learners have their own individual learning frame of references and act only upon processed information and their prior knowledge of a particular domain.

5.4.2 Memory
The most common explanations of memory activities are based on the information processing theory that uses the computer as a model to describe the human mental activity. Information processing can be described as follows:
1- Perceived information, received from the sensory memory, is encoded and sent to the working memory.
2- Necessary operations are performed, which may change the information form and content.
3- Processed information is stored in the long-term memory.
4- When needed, stored information can be activated to generate responses to it.
Cognitive psychologists consider the computer as only a metaphorical representation for human mental activity. Whereas, this research considers the cognitive scientists perspective for understanding memory processes by studying Artificial Intelligence, designing, and programming computers to reason and solve problems like we do.

5.4.3 Expertise

Experts have the intuition about how to solve a problem based on recognizing and matching the problem at hand with the large store of productions, condition-action schemas, and domain knowledge stored in their long-term memory. Expertise is a skill that features an automatic problem understanding, organizing information around central principles, planning the right actions, and monitoring the problem solving progress.

5.5 Processes

5.5.1 Metacognitive

Metacognition is a self-monitoring and self-control mental activity performed by the human brain during the learning process. The sensory memory initiates the executive control processes which direct the information flow through the information processing system.

Metacognition regulates and monitors the cognition machinery through control processes, also called metacognitive skills, such as:

1. Attention: the first step in learning is paying attention. In observational learning we gain new performance behavior and insight about what will happen in specific situations if we do perform it.

2. Rehearsal: it retains the information in the working memory as long as it is repeated.

3. Organization: it is structuring knowledge into a conceptual framework to improve the learning process.

4. Elaboration: it associates new information with another already stored in the long term memory. It is an executive control process that affects the flow of information through the information processing system.

«Metacognition is cognition about cognition or knowledge about
knowing» [7:260]. Metacognitive knowledge involves:

1- Declarative knowledge: the skills, strategies, and resources that influence the memory activities. It focuses on planning, monitoring, and evaluating the cognitive processes required to resolve certain problem.

2- Procedural knowledge: that describes different thinking approaches.

3- Conditional knowledge: that situates thinking processes according to the specific time and conditions.

5.5.2 Cognitive

Cognition is the comprehension and conception of the information. It is bound to the domain knowledge. An essential element of the cognitive process is learning that yields new mental representations and predispositions where knowledge is constructed and not reproduced. The cognitive theory is often called constructivism emphasizing new understanding of the world.

The cognitive process reflects problem-solving skills, creativity, attitudes, and the depth of understanding. It involves a reasoning criteria (formal, by analogy, or case-based) used to design and implement actions.

The main descendants of the cognitive process are:

1. Reasoning: there are two formal approaches to reasoning. The first is Inductive, proposed by Bruner, and suggests that people acquire knowledge through discovery in contrast to the second approach, proposed by Ausubel’s who viewed that concepts, principles, and ideas are presented and understood, not discovered.

2. Comprehension: “The German philosopher Wittgenstein realized that linguistic referents are the vehicles of our knowledge and comprehension of the world. [30]” Comprehension affects the knowledge constructed by the learners and therefore the conceptual structure of meanings, words, and sentences representing information.

3. Learning: is a result of active cognitive processes that yield new mental representations and predispositions [17].

4. Problem Solving: is a mental process that focuses attention on
identifying problems and opportunities, defining goals and representing the problem with the relevant details, understanding it, exploring possible solution strategies, selecting a solution and anticipating the consequences [7].

6 - Future Research and Recommendations

This paper suggested a taxonomic representation for the concepts of Knowledge and Intelligence. Knowledge being the main substance matter for any Intelligence concept, Knowledge taxonomy can be considered as a sub-tree or an extended branching for the Intelligence taxonomy.

Taxonomic representation for Knowledge and Intelligence helps unify, standardize, and conceptualize related terminologies and their interrelationships.

Knowledge and Intelligence taxonomies can be integrated together in various ways depending on the domain knowledge and contextual information required. In addition, they can be embedded into organizational ontologies to expand the organizational memory capacity and intelligence power.

One such application is to build a common and integrated infrastructure between various academic disciplines which would tighten or otherwise reveal the hidden conceptual links between knowledge objects, sources, and forms as well as the existing cognitive elements, both human and artificial.

Finally, Knowledge and Intelligence taxonomies form the basic framework for human intelligence concepts and add potential perspectives for Artificial Intelligence development.

7 - References


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