Call from the South for a Transparent Higher Education (THE) Part 3: Expanded TTA Conceptual Framework and Its Applications in Math, Science, and Engineering Education

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The world sailed in the new millennium with a heavy burden of problems. This series of three articles is a call from the south to relieve these burdens by building a conceptual framework for a Transparent Thinking Approach (TTA). Part 1 covered Transparent Orientation (TO) and Transparent Solution (TS) evolution in preparation to present the core of TTA conceptual framework. Part 2 covered Transparent Presentation (TPr) tools in preparation to present the extended TTA conceptual framework. Part 3 covered the implementation of the Extended TTA in constructing a Transparent Higher Education (THE) with Math, Science and Engineering Education examples.

TRANSPARENT ORIENTATION (TO)

In part one and two of this series of articles TTA core and extended conceptual framework, respectively, was presented. In this article (third and final part), TTA expanded conceptual framework and its application in the Math, Science and Engineering domain are presented.

EXPANDED TTA CONCEPTUAL FRAMEWORK

Transparization of Thinking

Human thinking is considered as one the most complex phenomena on this earth. Wide spectrum of definitions for human thinking is developed. It is seen as narrower than the notion of "cognition" and as wider than the notion of "reasoning". Thinking is, thus, seen as a part of cognition processes; and reasoning processes are seen as a subcategory of thinking. Similar to reasoning, the notion of thinking includes also intuitive and associative processes of linking mental structures (Glatzeder et al, 2010).

Mosely et al 2005, stressed that the term 'thinking' can be used in many senses. It can be used to describe mental activity that we may be partially conscious thought to the more conscious acts of reflecting or bringing to attention particular aspects of our experience. Mosely et al. (2005), shows that the word 'thinking', particularly in educational contexts, is usually used to describe a consciously goal-directed process, such as remembering, forming concepts, planning what to do and say, imagining situations, reasoning, solving problems, considering opinions, making decisions and judgments, and generating new perspectives.

In this series of articles, thinking is extended to be the big umbrella that includes all processes that the mind undergoes either in cognition, connation, or affection domains. The inclination to adopt this extension is because the three domains are of great importance in affecting learning and understanding, as illustrated in FIGURE 1. Mind is enclosed inside a number of nested accommodating environments: body, social environment, physical and metaphysical universe, as illustrated in FIGURE 1. The interaction of the mind with the constituents of each environment creates multi forms of intelligence such as cognitive, connative, affective, spiritual, natural, interpersonal, intrapersonal, metacognitive, etc.... In FIGURE 2, analogy between a car and mind (human learning machine) is employed to clarify in simple terms the important the three domains of the mind (Cognition, affection and connation) and their interaction in creating a balanced performance of the mind. Fuel for the car is similar to connation and will in fueling human actions; motor of the car is similar to cognition in creating the driving mechanisms; and motor oil is like affection in lubricating gears and creating meaning in the mind. All the three parts are needed to create a balanced human performance. Focusing on cognitive processes while neglecting the affective and connative aspects is like having a motor without fuel and oil.

To help in understanding the extended notion of thinking, FIGURE 3 graphically gathered diverse life activities that thinking plays a very important role in them. It can be concluded that all our living on this life is based on thinking as a crucial process for accomplishing our daily activities such as studying, playing chess, fighting, working, eating, dancing, etc…. Thinking process is the micro scale process that stands behind all our actions and reactions. Thinking is the process of making learning happen.

FIGURE 1
DOMAINS OF THE MIND ACCOMMODATED IN NESTED ENVIRONMENTS AND ITS CORRESPONDING INTELLIGENCES

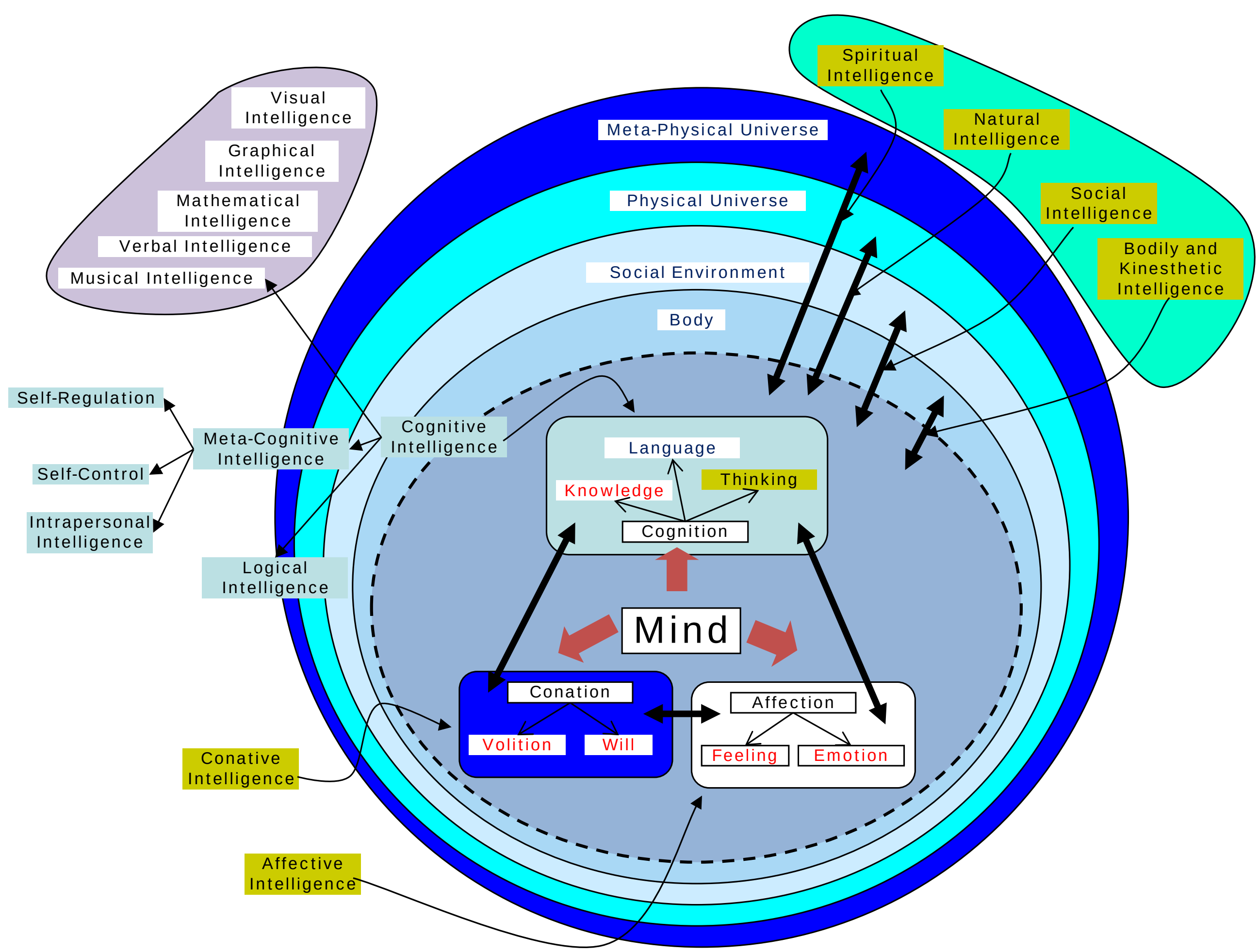


FIGURE 2
ANALOGY BETWEEN THE CAR AND THE DOMAINS OF THE MIND TO REVEAL THE DEEP CONNECTION BETWEEN THEM

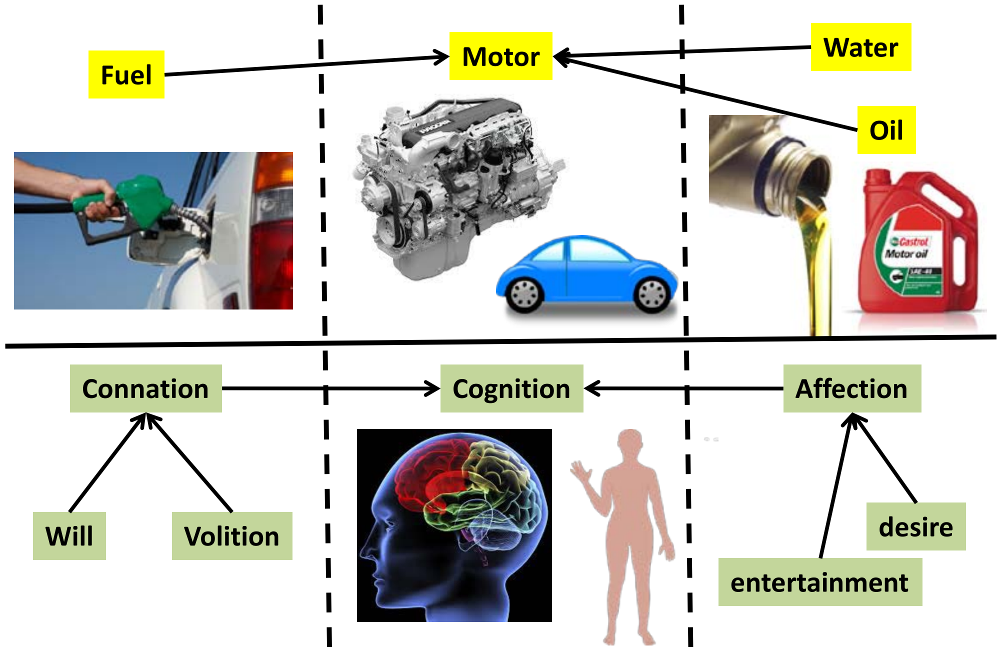
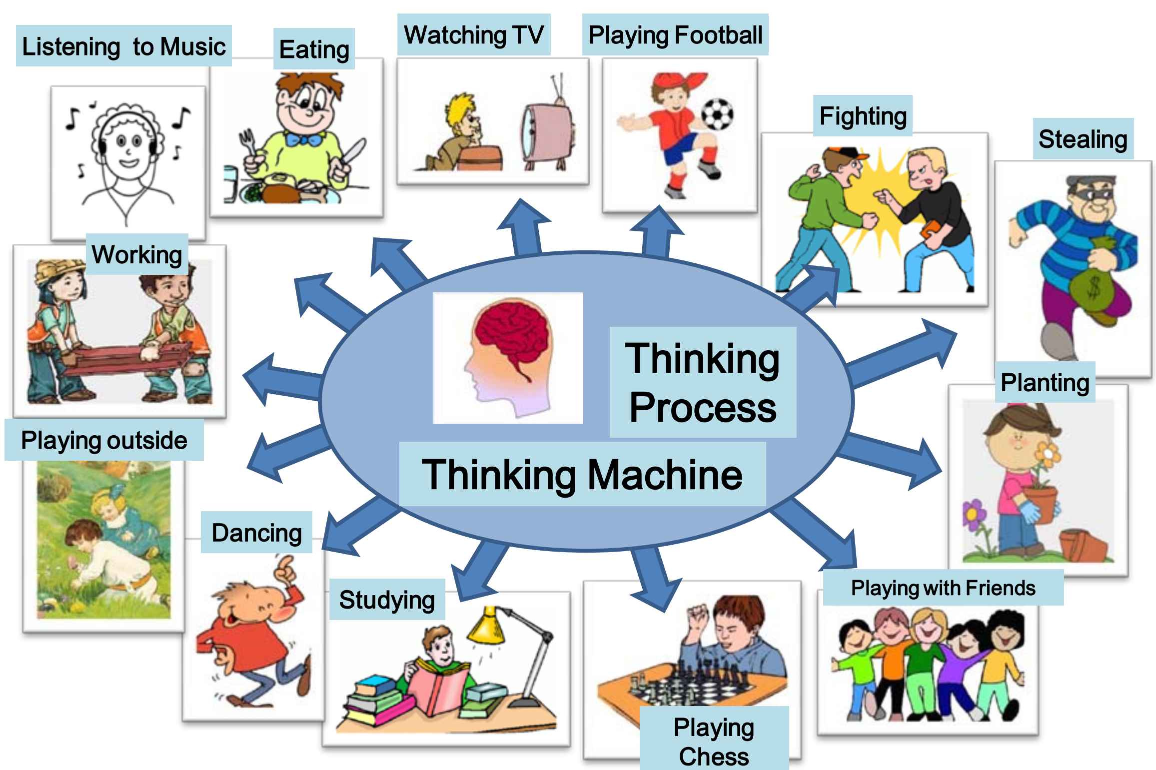


FIGURE 3
THE EXTENDED CONCEPT OF THINKING IS ILLUSTRATED BY NUMEROUS EXAMPLES IN DIFFERENT FIELDS



The Relevance of Thinking

"The greatest discovery of any generation is that human beings can alter their lives by altering their attitudes of mind." William James

Humans are probably mainly characterized by their ability to think in a complex way. Glatzeder et al, 2010, stressed the relevancy of human complex thinking ability that appears to be of particular importance in the following areas:

1. Thinking is the most important mechanism through which the richness, interrelatedness, and coherence of reality uncovered to us, and which is crucial for answering the question "what makes us human".
2. Thinking and reality mutually interact to shape each other.
3. Because of the increase in complexity of our modern world, further advancements in our thinking skills are required to be affected.
4. In an increasingly knowledge-based economy, thinking is the main value generation process.
5. Learning, understanding, making connection, forming concept, generating ideas, proposing solution, and other intellectual activities are all products of thinking. (Glatzeder et al, 2010)

Thinking as the Process of Learning

Thinking is a non-stop physiological process that starts from human birth and end by death. The brain is the thinking machine that undergoes all mental processes needed for a human to be able to create meaning from the surrounded complex world, and to strengthen or change beliefs, values, behaviors, and attitudes. Learning is one of the most important products of thinking. Thinking is the process that is used to affect learning. Deep thinking normally results in richer and more meaningful learning.

Learning as a Process of Change

Ormrod, J. E., (2012) in her book that is entitled "Human Learning" presented a definition for learning as follows:

"Learning is a long-term change in mental representations or associations as a result of experience, through which learner acquires skills, knowledge, values, attitudes, and emotional reactions." Ormrod (2012)

Ormrod definition can be transparized (analyzed transparently) to reveal the following components:

1. learning is a long term change process
2. learning is accomplished by the brain (Learning Machine)
3. learning result in two forms of product (changes);
   a. first, hidden products in the form of changes in the mental representation and associations;
   b. Second, a relatively transparent change products in the form of acquired skills, knowledge, values, and emotional reaction.

Ambrose et al. (2010) also defined learning as:

"Learning is a process that leads to change, which occurs as a result of experience and increases the potential for improved performance and future learning"

Ambrose et al. (2010) definition also can be transparized to show its critical components:

1. Learning is a process.
2. Learning takes place in the mind. Therefore Learning is not something done to students, but rather something students themselves do.

3. Learning product involves change in knowledge, beliefs, behaviors, or attitudes.

The result of the transparization process to thinking, learning and change result in finding that thinking is the micro process of learning and both of them are processes of change.

Education as a Process of Revealing Hidden Connections

Faclav Havel, the politician, artist and poet, offered a definition of learning as:

> *"Education is the ability to perceive the hidden connections between phenomena" Vaclav Havel*

Einstein and Infeld in their book "the evolution of physics" described deeply the important role of scientists' analogy between phenomena that seems distant and how these phenomena look after being deeply and analogically analyzed.

> *"It has often happened in physics that an essential advance was achieved by carrying out a consistent analogy between apparently unrelated phenomena….The association of solved problems with those unsolved may throw new light on our difficulties by suggesting new ideas. It is easy to find a superficial analogy which really expresses nothing. But to discover some essential common features, hidden beneath a surface of external differences, to form, on this basis, a new successful theory is important creative work." Einstein and Infeld*

This quote from two well-known scientists indicates the important role that analogy plays in transparizing our understanding of the surrounding phenomena and usually ending in discovering useful connections. The above two quotes are leading us towards adopting an extended framework for learning. Anything new to us is representing a black box that we try hard to reveal what it contains. In other words, transparizing what is inside these black boxes is a process of learning. This process of learning or "transparizing" is Transparent Learning Process (TLP).

Transparization of the Learning Machine

Human Brain is an extremely complicated organ that consist of approximately one hundred billion nerve cells. These nerve cells are connected to make a huge network. Ormrod, J. E., (2000), summarized the following brain key role in learning and cognitive development (Ormrod, 2000):

1. Most learning probably involves changes in neurons and synapses (connections between neurons). Namely there are physical changes occurs in the brain as a result of learning
2. Development changes in the brain enable increasingly complex and efficient thought, which confirms what is simply said "use it or lose it"
3. Many parts of the brain work in harmony to enable complex thinking and behavior. There is specialty for some parts of the brain to do certain jobs but all of its parts integrate to achieve most of the jobs.
4. The brain remains adaptable throughout our life. In general, no late time for taking action to develop our mental abilities.

These are key roles of our learning machine leads us to think seriously about how to understand these key roles and adapt them to enhance learning and understanding. To be able to learn or teach in an efficient and effective way, learners (educators and students) should understand the performance of this machine in a better way (how we learn? And how we teach?).

How Our Learning Machine (Brain) Works?

Over the past two decades, a significant progress in neuroscience, especially in neurobiology, psychology, and artificial intelligence is accomplished. As educators we should take advantage of that progress, recognizing that the coming years will bring more progress. By clarifying the structure and how the brain functions, we can obtain clues on how to improve learning (Haile, J. M., 1997a).

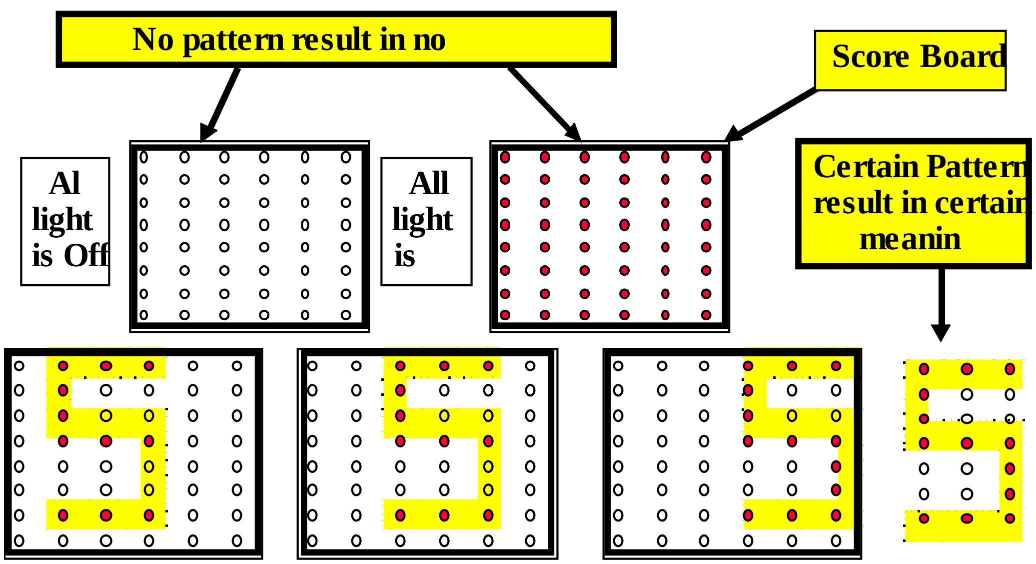
The basic unit of mental activity is a single nerve cell (the neuron). Functionally, a neuron in the cortex collects signals from other neurons, integrates them into a single signal, and then either suppresses the signal or forwards it to other neurons. The collective neural firing of a group of neurons is what creates meaning in our mind. Therefore, firing a single neuron can generate no meaning. The cluster of neurons that form a certain structure fires collectively to give a certain meaning (Haile, J. M., 1997a).

Although the functioning of a single neuron is a fascinating electrochemical process, the really remarkable functions occur not at the molecular or cellular levels, but in the collective behavior of large numbers of connected neurons, which is called neural network. By itself, the firing of a single neuron is essentially meaningless. Meaning only formulates when a pattern is established by the simultaneous or sequential firings of many neurons. This fascinating collective work of different groups of neurons can be illustrated by a very informative analogy, which is the scoreboard (Haile, J. M., 1997a).

Brain Transparization Using Neural Firing Scoreboard Analogy

Scoreboard analogy is an efficient way of transparizing the fascinating process of collective work of neurons to create meaning in the mind of the learners. FIGURE 4, is drawn to illustrate how this coordination between scoreboard lamps is creating meaning that is displayed on the screen of the board.

FIGURE 4
NEURAL FIRING ANALOGY



As mentioned above, the firing of a single neuron is essentially meaningless. Meaning only arises when a pattern is established by the simultaneous or the sequential firings of collection of neurons. The scoreboard analogy is used to illustrate the collective action of the neural network. As shown in FIGURE 4, imagine an array of lights forming a scoreboard. The array itself has no meaning; if none of the lights are activated, we have no meaning, and if all lights are activated, we still have no meaning. Informative meaning occurs only when some lights are activated while others are not. Moreover, the meaning is in the pattern, not in any particular lights. Meaning is encoded in the spatial and temporal relations among the lights that are activated and those that are not. For example, meaning is preserved even when the pattern scrolls across the array. As shown in FIGURE 4, the lights in the scoreboard represent the neurons, the whole lights array represents the neural network and the moving pattern represents a certain firing in the neural network (Haile, 1997a).

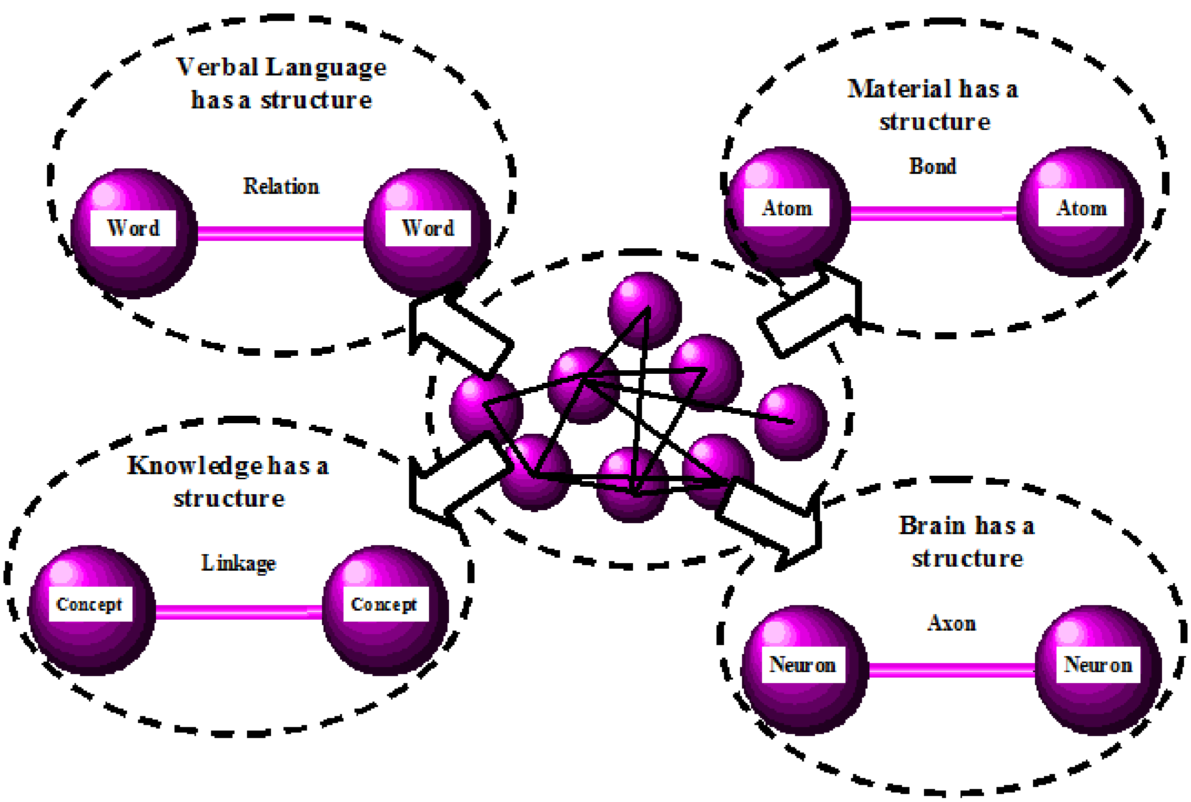
Transparization of Knowledge Construction

Knowledge has a Structure

As illustrated in FIGURE 5, everything in nature has a structure: materials has a structure of atoms bonded to each other; human brain has a structure; verbal language has a structure of words, phrases and sentences; and also knowledge has a structure of thoughts, facts, and concepts.

Scientific knowledge has a structure that hierarchically organized with the fundamentals at the higher levels and pointers at lower levels (Woods et al, 1993). Cognitive psychologists believe that learning involves constructing learner's own knowledge from one's experience. Educators should build and use the appropriate structure to enhance learning and problem solving. Scientific knowledge is not a collection of unrelated equations that we use to solve problems. The subject is built upon fundamental laws and concepts that allow us to use those laws, models, theories, semi-empirical correlations, and data (Woods et al, 1993).

FIGURE 5
KNOWLEDGE HAS A STRUCTURE



Structured Knowledge Processed in a Structured Machine

The Brain has a structure of a huge network of neurons that work together in harmony to create meaning. The meaning is created when a group of neurons in a certain part of the brain fires a signal. By itself, the firing of a single neuron is essentially meaningless. Meaning only arises when a pattern is established by the simultaneous or sequential firings of many neurons (collective action of neurons in a network).

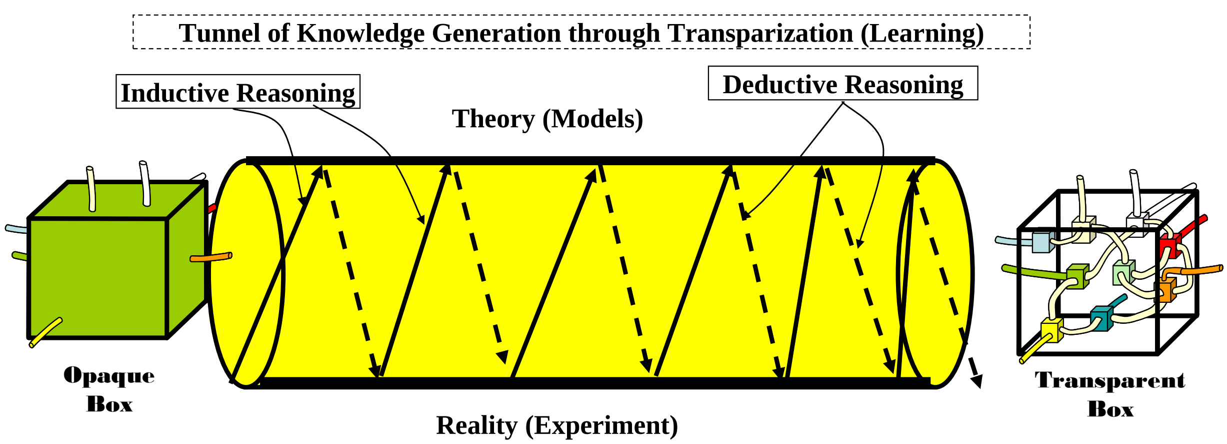
The brain is the machine that is used to process knowledge. Getting a peek on the structure of this machine and how it works will help to answer the question why knowledge is structured. Similarly, knowledge has a structure. One piece of knowledge is meaningless without a connection to another piece of knowledge, to an application, or to a context. The true meaning arises when these pieces of knowledge are fit together to form a structure.

Knowledge Generation Through Transparization

Humans' life is distinguished by being a life-long transparization (learning) process. Humans regularly have black box to investigate and transparize in order to get more insights and understand what is going on inside, as shown in FIGURE 6. This journey of transparent learning (Opaque boxes transparization) started thousands of years ago and still going on forever. Opaque box transparization is like moving into a dark tunnel seeking more light in order to get clearer understanding of everything in the surrounding environment. Humans, in their straggle to get more insights, are iterating between theory and reality using inductive and deductive reasoning as shown in FIGURE 6. In their straggle to get knowledge to improve their life, humans developed their scientific methodology of research. This methodology is based on physically experimenting with nature on one side, and then analyzing the results based on theoretical understanding and conceptual models of what they think really occurs (Box, G. E. P. et al, 1978). This oscillation (Dynamic Maneuvering tool discussed in Part 2) between theory and experiment is the mechanism that is discovered for gaining new knowledge. Humans usually start there learning journey with a relatively black (opaque) box understanding, but this black box gets more transparent as scientists iterate between theory and experiment to get more insights about what is going on inside that black box. Research helps us to transparize the black box in order to reveal its content. The process of knowledge generation (Transparent Learning or Transparization) is symbolized by a black box that is gradually getting to be a transparent box (as conceptualized in the core TTA conceptual framework).

An increasing number of teachers are using black box activity to help the student to practically understand the deductive-inductive reasoning of the research process. This activity motivates students to think in scientific way and offers them the opportunity to think scientifically.

FIGURE 6
CONCEPTUAL GRAPHICAL MODEL OF KNOWLEDGE GENERATION USING ORDINARY SCIENTIFIC RESEARCH WITHIN THE PERSPECTIVE OF TRANSPARENT THINKING APPROACH (TTA) (BASED ON A FIGURE IN BOX, G. E. P., 1978)



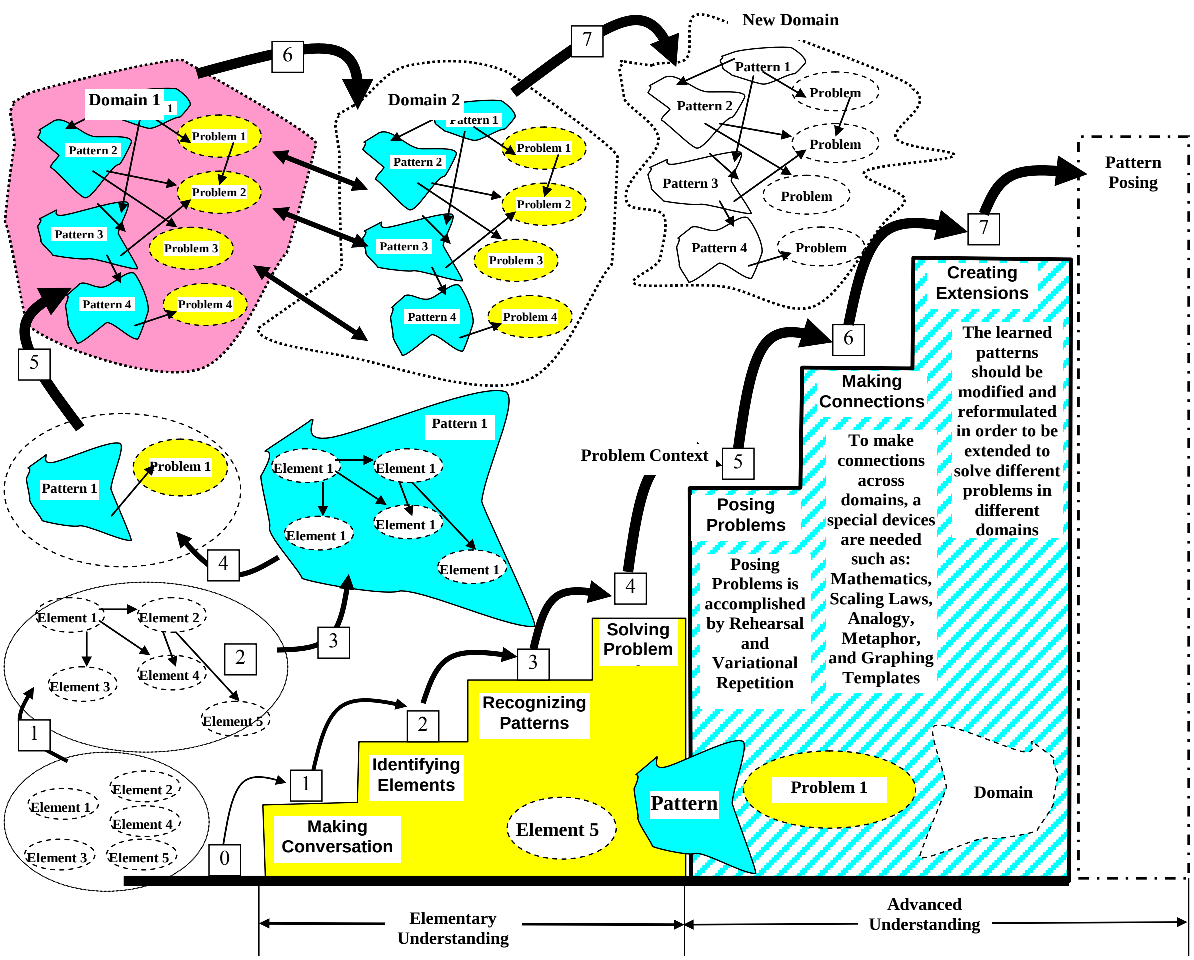
Transparization of Technical Understanding

Transparization of Haile's Cognitive Hierarchy of Technical Understanding

Haile, J. M. (Haile, J. M., 1997a, b, and Haile, J. M., 1998) developed an excellent hierarchy for technical understanding. A graphical conceptual model is developed in this article for this hierarchy to help in transparizing the levels proposed for technical understanding as shown in FIGURE 7. FIGURE 7 is a trial to present Haile's technical understanding levels in graphical and metaphorical form and to connect it with the constructivist understanding for learning as the ability to construct knowledge and make connections. Haile's new framework of technical understanding includes seven levels which are as follows: (1) Making conversation, (2) Identifying elements, (3) Recognizing patterns, (4) Solving Problems, (5) Posing Problems, (6) Making connections, and (7) Creating extensions. Haile's also predicted an 8th level which is called pattern posing as shown in FIGURE 7.

At zero level of understanding in Haile's Hierarchy (see FIGURE 7), the process started with seed knowledge in the form of identified elements. As the learner initiate the processing of the seed knowledge, then the process of identifying element (stage 2) started. At this level, the learner starts to be able to talk about fragmented elements which is called making conversation (stage 1) and identify these elements (stage 2). At level 3 (recognizing pattern), the learner deeper understanding will help in recognizing a relationship between the identified elements in a form of certain pattern. At the fourth level (problem solving), the learner will be able to make connections between the identified pattern and certain

FIGURE 7
GRAPHICAL CONCEPTUAL MODEL THAT ILLUSTRATES OF HAILE'S TECHNICAL UNDERSTANDING MODEL



problem that is needed to be solved. At level 5 (Posing problem), understanding process is accompanied by rehearsal and variation of representation. Level 5 of understanding will help the learner in creating a linkage between different patterns with different problem contexts. The ability of the learner to dynamically maneuver between patterns and problems will prepare him to maneuver between different domains. At the next advanced understanding level (Level 6: making connections), the learner should have the ability to transfer the relationships constructed in certain area to another domain of knowledge. Maneuvering between domains is a very important characteristic of advanced learners. In the next and the most difficult level (Level 7: Making extensions), the learner should be able to make extensions, modify and reformulate the patterns in order to be extended to a newly different domain of knowledge.

Getting insight on how the learner understands technical material is a very important for the instructors to acquire. However, the challenge is now in how technical educator can design an instructional material and a learning environment that help our students to reach higher level thinking skills in these hierarchies? (Haile, J. M., 1998)

When we say a taxonomy or a hierarchy of technical understanding, it means building a structure of technical knowledge operations. Seeking to build a taxonomy or hierarchy is part of the effort to build a coherent structure for the whole scientific knowledge generation and understanding.

Transparizing Meaning Through Making Connections

The overriding theme of Haile's Technical understanding hierarchy (Haile, J. M., 1997a, b, and Haile, J. M., 1998) is that anything interesting and useful has multiple meanings and understandings. Those meanings arise out of connections. Connections can be either: (1) among objects and concepts to form meaningful patterns, (2) between patterns and problem context, (3) among different problems and their context, (4) among different domain of knowledge.

Haile's hierarchy of technical understanding provides a scheme for systematically making connections. The hierarchy of understanding can be used by instructors to:

1. help organize how material is presented to students
2. help the assessment of their comprehension
3. Identify what should be done to move to the next level.

Evolution of Transparent Learning Theory (TLT): Transpirism

Theories of learning explain the hidden mechanisms involved in learning. The current understanding of learning process is developed over the years by researchers used different approaches to the study of human learning. When psychologists first began to study learning in the late 1800s, the two dominant perspectives in psychology were structuralism and functionalism (Ormrod, 2012).

In the early 1900s, some psychologists began to criticize these perspectives for lack of scientific rigor. Beginning in the early 1900s, many psychologists emphasized the behavior in their study of human learning in a learning perspective called behaviorism. Behaviorism focuses on the environmental factors by identifying cause-and-effect relationship between stimuli and responses in human behavior. Behaviorists proposed that to study learning in an objective, scientific manner, theorists must focus on two things that can be observed and objectively measured: people's behaviors (responses) and the environmental events (stimuli) that precede and follow those responses. The behaviorist perspective has contributed immensely to our understanding of how people learn and how instructional and therapeutic environments might help them learn more effectively. Behaviorism revolves around three key assumptions: (1) Observable behavior rather than internal thought processes, (2) The environment shapes one's behavior, (3) reinforcement are central to explaining the learning process (Ormrod, 2012).

But in the 1940s, some psychologists proposed that people can also learn a new behavior simply by watching and imitating what other people do. This idea of modeling provided the impetus for an alternative perspective (social learning theory) that examined how people learn from observing those around them (Ormrod, 2012).

Over time, as psychologists increasingly explored many different facets of human learning, it became clear that a study of behavior alone couldn't give us a complete picture of learning. By the 1960s, learning theorists started to shift their focus to include thought in addition to behavior which is emerged to be cognitive psychology. Cognitivism developed scientific methods for studying a wide variety of mental phenomena: perception, memory, problem solving, reading comprehension, and so on. Social learning theorists, too, gradually incorporated cognitive processes into their explanations of learning, resulting in a perspective now more often referred to as social cognitive theory. The cognitivist approach stressed that the “black box” of the mind should be opened and understood. The learner is viewed as an information processor (like a computer). Cognitivism focuses on the inner mental activities – opening the “black box” of the human mind is valuable and necessary for understanding how people learn (Ormrod, 2012).

Based on Lev Vygotsky’s early ideas, in the past two or three decades some psychologists have developed theories about the critical roles that social interaction and culture play in human learning and cognitive development. These developed theories most widely used label is socio-cultural theory (Ormrod, 2012).

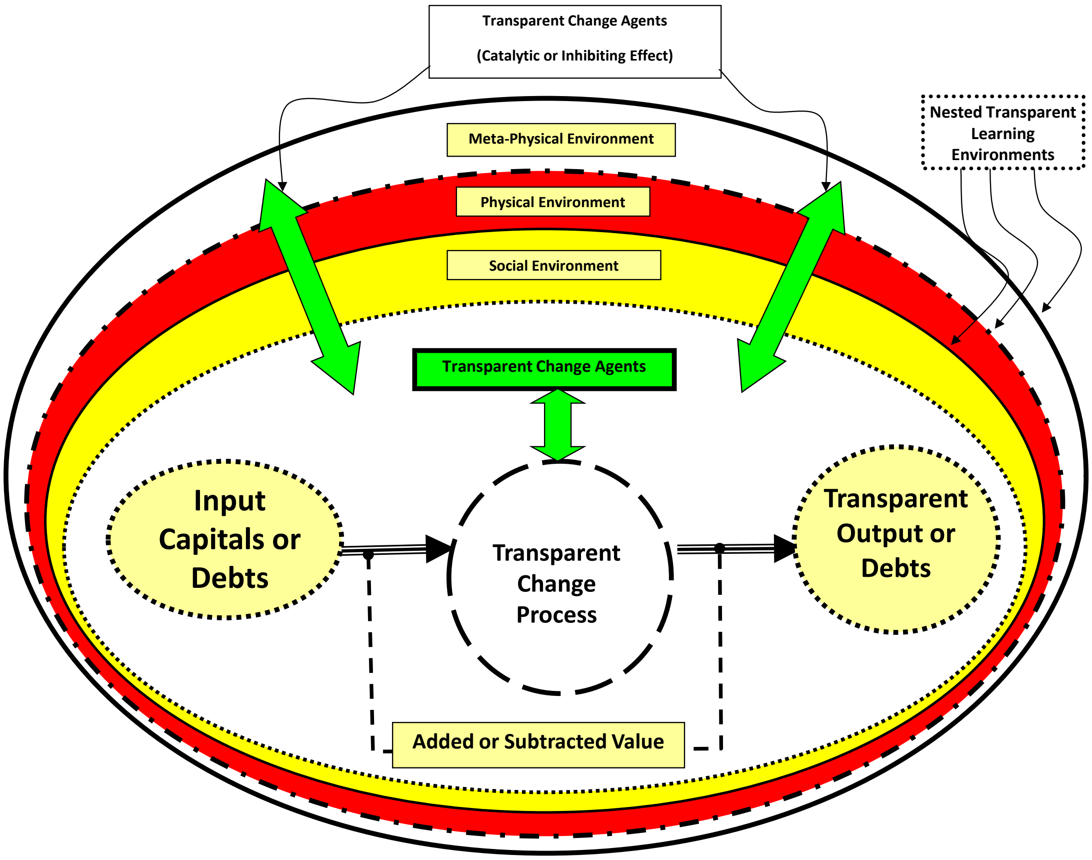
The constructivism theory of learning is one of the major theories that contributed to affect a big change in the view of teacher and learner roles in the educational setting. Constructivism looks at learner as the center of the educational process and that the teacher is facilitating the learning process. Constructivism evolved to inter the social arena by what we call Social Constructivism, which stressed the role of the social interaction in enhancing the effectiveness of learning process. Constructivism views learning as a process in which the learner actively constructs or builds new ideas or concepts based upon current and past knowledge. Constructivism looks at learner as a constructing his/her own knowledge from his/her own experiences.

The building of the generic core Transparent Thinking Approach (TTA) conceptual framework based on transparency as a seed core value was the rigid foundation for the utilization of the instrumental value of transparency to be extended to encompass a cluster of important core values. This cluster of core values stimulates the crystallization of 42 thinking skills in the form of Expanded TTA conceptual framework. The ability of TAA to diffuse, germinate, or crystallize is the one of greatest advantages of TTA. This important characteristics are represented by the ability of TTA to develop tools such as Dynamic Maneuvering (DM) and Transparent Modeling (TMd). Dynamic maneuvering enabled the Transparent Thinker to freely maneuver between scales, domains, paradigms, theories, disciplines, meanings, context, etc… This dynamicity, adaptability, genericness, simplicity of expanded TTA enabled it to diffuse easily to learning and understanding domain using transparization as an effective learning and understanding tool. The Dynamic Maneuvering that is adopted in reviewing the learning theories above, gets us to conclude that Expanded TTA is the incubator that will accommodate all the current learning theories to fruit the bigger umbrella of Transparent Learning Theory (TLT) as future learning theory.

Diffusion of TTA to Change and Development Domains

Dynamic maneuvering in the learning and understanding domains (Education) is leading us to get to conclude that change is the one word that summarized life in this universe. Change is the big umbrella that accommodate all the processes that happening in our universe. Development, reaction, production, growth, learning, understanding, transformation, revolution, eruption, heating, cooling, construction, transfer, etc… are all processes of change. As transparized in FIGURE 8, any process is having inputs and outputs; immersed into nested environments; and get affected by agents. These inputs or outputs can be anchored by the generic form of capital or debt, and agents can be in the form of catalysts or inhibitors. The dynamic interaction between the process inputs, outputs, agents and environments is makes change accelerate or decelerate. This is the transparent way of seeing the processes in this universe. Transparization revealed the connecting string between thinking, learning, education, development and eventually change.

FIGURE 8
DIFFUSION OF TTA TO THE PROCESS OF CHANGE



APPLICATION OF EXPANDED TTA: TRANSPARENT HIGHER EDUCATION (THE)

TTA diffused to the learning and understanding domain to result in an expanded concept of transparization. TTA is piloted in Higher education setting (Mutah University, Jordan) over the last ten years while teaching math, science and engineering courses to Engineering Students. Therefore, the examples that will be presented will be in these fields.

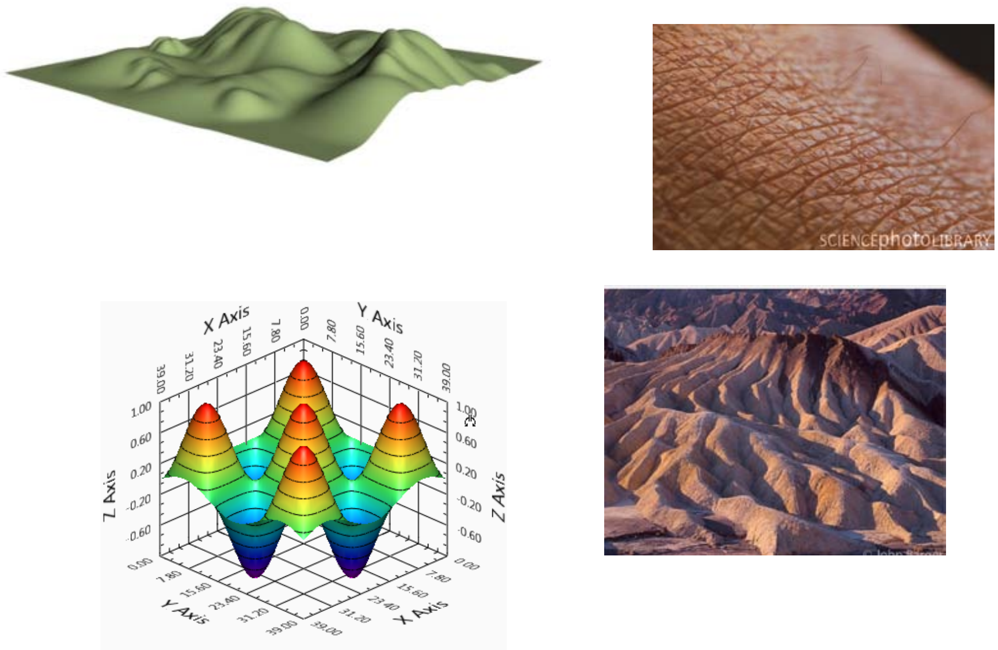
TTA Application in Math Education: Transparent Math Education

Mathematics education is the hardest to transparize due to its intrinsic abstract nature of its content knowledge. Math textbooks are traditionally written in an abstract way that is disconnected from its application. The most important question that most students are usually asking when they took a math course are the following:

1. What are the deep meanings of these concepts?
2. What is the conceptual framework that connects between these concepts?
3. What are the benefits of using these math concepts?
4. What are the applications that employ them?

TTA can offer the answer for these important questions by employing its supportive diagnosis and modeling tools. Large number of practices is used over the last ten years and the following examples represent a glimpse of this accumulated experience.

FIGURE 9
PHYSICAL REPRESENTATION OF MATHEMATICAL SURFACE FUNCTION



Transparization by Dynamic Maneuvering Between Abstract and Physical Domains

The concept of limit existence is important in building continuity and differentiability concepts in calculus courses. The three concepts are interrelated to constitute the base for differential calculus. The first step in the transparization process is to clarify to students that the mathematical function is not just a group of samples that are fused together to form an equation, but it is can represent a physical surface such as terrains surface, or skin surface as illustrated in FIGURE 9. It should be kept in the student's minds that mathematics is the language that is used to represent a physical real entities and it is created to serve in representing the physical objects and phenomena in real life situations. Students in math classes are getting used to be isolated from the physical domain and to deal with mathematics in abstract way. Getting the students to believe that the physical reality is our base domain. Math learners leave the physical domain temporally to the mathematical abstract domain and then get back again to it to get insight.

Transparization by Sharing Experience with Created Comic Characters

Another type of transparization methods is to create two comic Jordanian characters (Falhan And Watban-funny arabic names) and to use them share the student in physically feeling the intuitive meaning of the function and the existence of a limit by walking over the physical surface to look for gaps, holes, or cliffs, as illustrated in FIGURE 10. The crawling babies will represent being close to the function surface to feel the existence of gaps, holes, or cliffs that may hinder the existence of limit. Shaking hands of the two comic characters will indicate that the limit exist even if there is a hole in the surface, see FIGURE 10 . As will be illustrated later, holes do not hinder limit existence but it will hinder continuity.

Employing comic characters to share students getting the physical intuitive insights of the three important differential calculus concepts (limit existence, continuity, and differentiability) are illustrated in FIGURE 11. Limit existence is connected physically with shaking hands, continuity is connected with gaps and holes, and differentiability with shaking slopes.

FIGURE 10
FALHAN AND WATBAN (COMIC CHARACTERS) EXPERIENCING PHYSICALLY THE PHYSICAL IDEA OF A FUNCTION AND LIMIT EXISTENCE

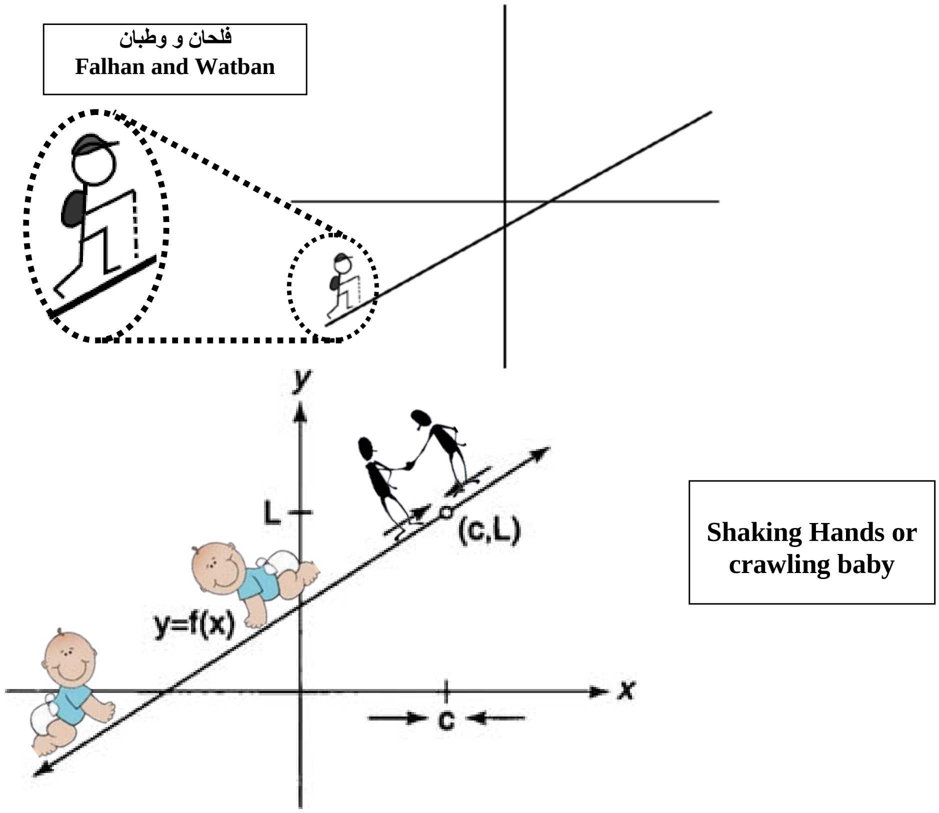


FIGURE 11
CONNECTING LIMIT, CONTINUITY, AND DIFFERENTIABILITY USING PHYSICAL INTUITIVE INSIGHTS

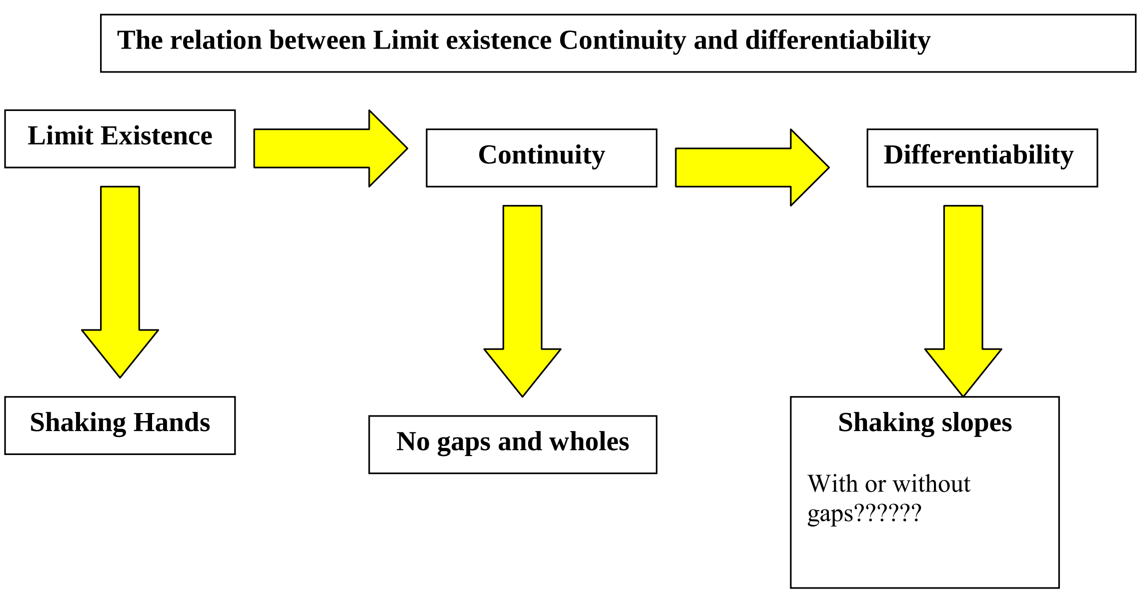
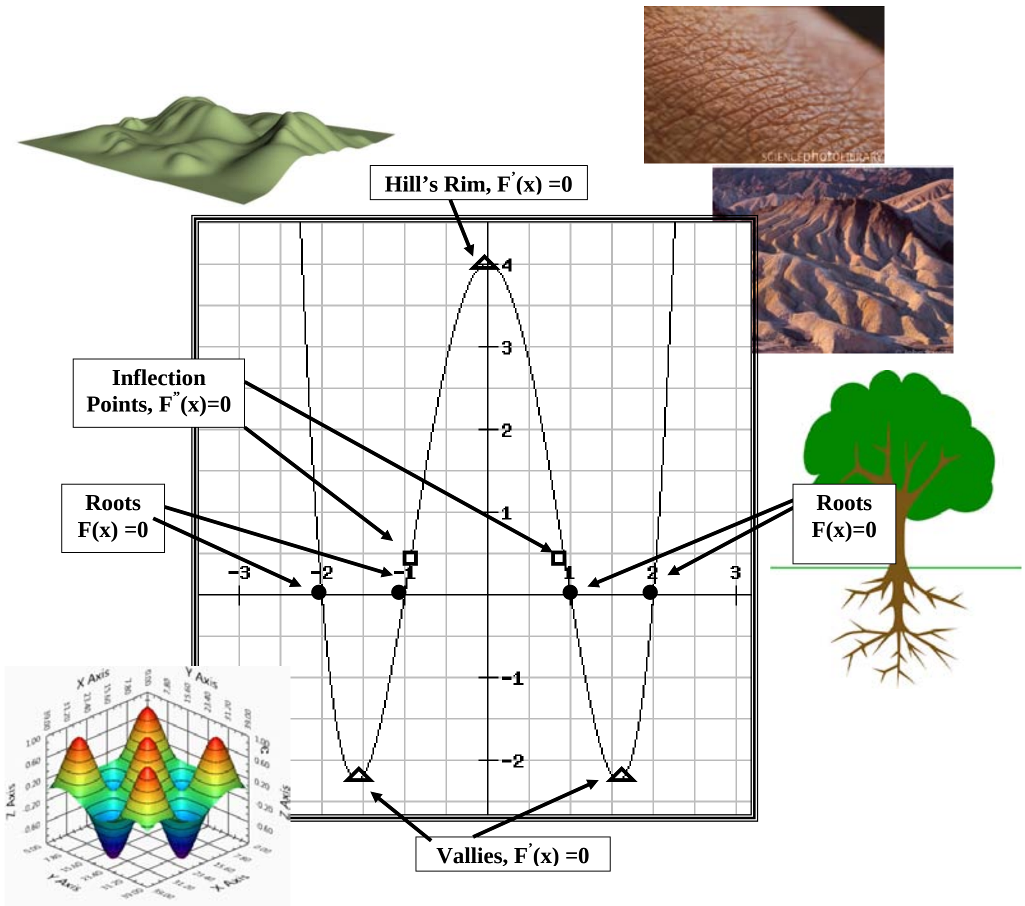


FIGURE 12
ILLUSTRATION OF THE MOST IMPORTANT FEATURES OF A FUNCTION: ROOTS, PEAKS AND VALLEYS, AND INFLECTION POINTS

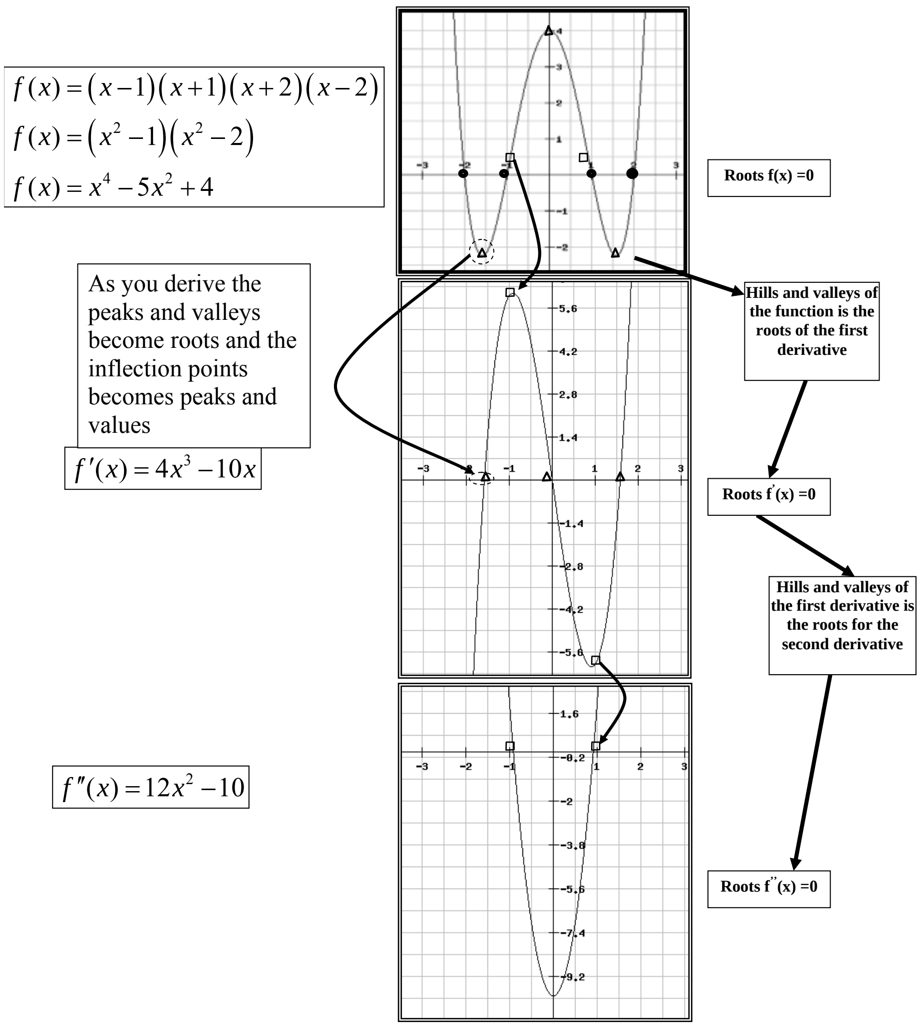


Transparization by Creating Physical Feeing Analogy (Terrains Features)

Building an intuitive understanding of three functions features (roots, maximum and minimum, and inflection points) is a perquisite to create a relation between the function and its first and second derivatives. The behavior of the function and its first and second derivatives will determine the concavity, maximums and minimums, as illustrated in FIGURE 12.

The relation between the function and its first and second derivatives is illustrated by drawing them simultaneously as shown in FIGURE 13. This figure shows how the function plot is changing when differentiated and how the peaks and valleys become roots and the inflection points become peaks and valleys. The change in physical behavior is directly related with the change in mathematical behavior. DM between mathematical and physical domains is essential in building deeply ingrained concepts in the mind of the students.

FIGURE 13
DRAWING SIMULTANEOUSLY THE GRAPH FOR A FUNCTIONS AND ITS 1ST AND SECOND DERIVATIVES TO ILLUSTRATE HOW THE GRAPH IS CHANGING WITH DIFFERENTIATION



TTA Application in Science Education: Transparent Science Education

Simple real experiments are one of the most effective transparization methods used to apply TTA, because it helps in affecting an easy transfer of concepts to the mental construct of the students. Talking theoretically for an hour about convective currents is not as effective as letting the student to conduct a 5-minutes simple experiment for illustrating the convective currents by adding a dye to an enclosed glass tube and then heat the glass tube to let the convective currents move the colored dye, as shown in FIGURE 14. The concept metal thermal expansively can be similarly transferred easily to students' minds by using letting students conduct a very simple ball and ring experiments shown in FIGURE 15. These simple experiments will save time and effort and get the concepts to be engraved in the mental construct of the students.

FIGURE 14
CONVECTIVE CURRENTS EXPERIMENT USING DYE AND ENCLOSED GLASS TUBE

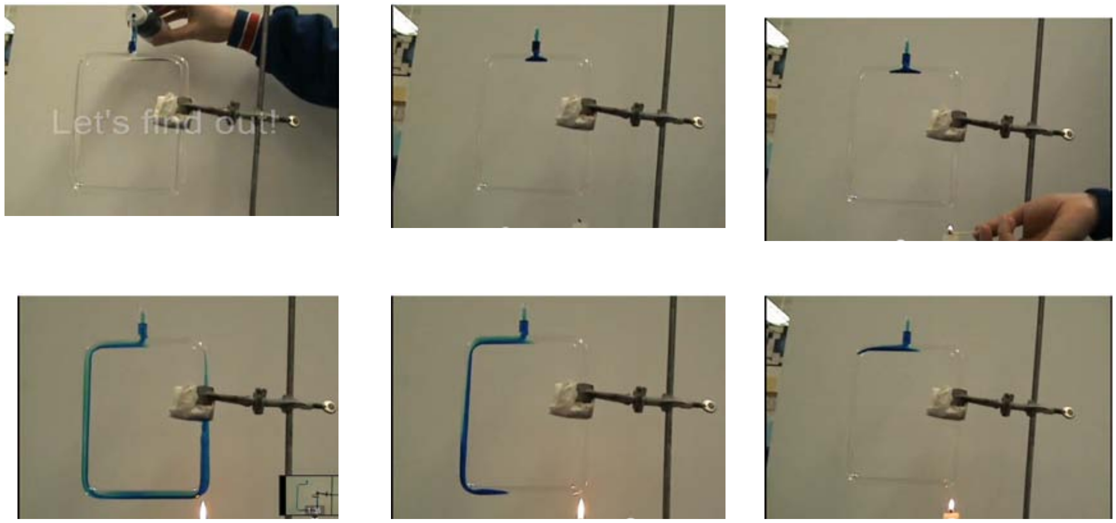
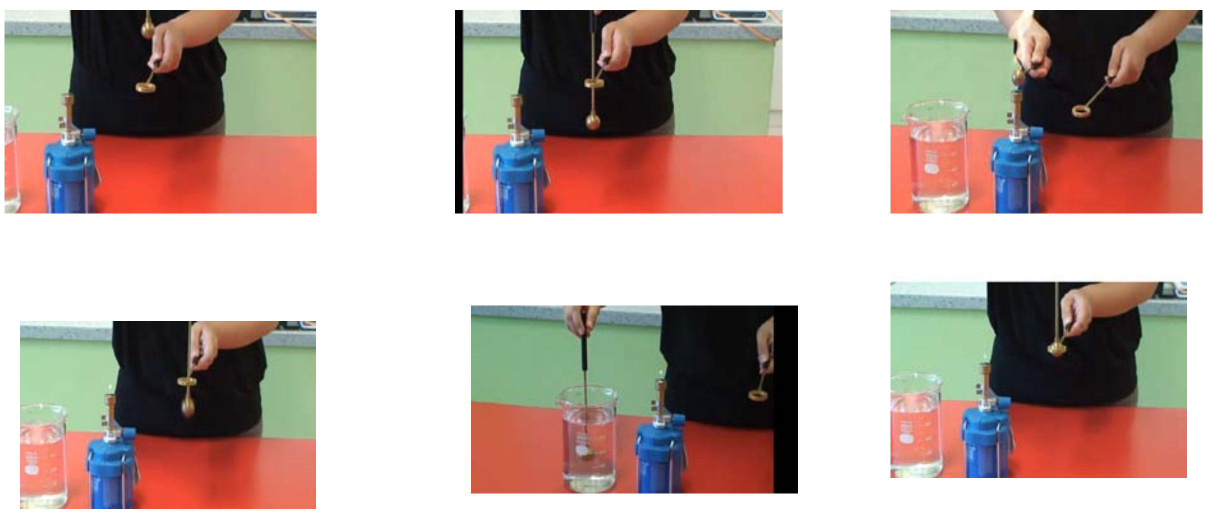


FIGURE 15
METAL THERMAL EXPANSIVITY EXPERIMENTS



Salt solubility behavior in water is another activity that shows how the solubility of different salts behaves differently. As shown in FIGURE 16, KNO3 solubility increases sharply as temperature increases, but on the other hand sodium sulphate solubility decreases sharply with increasing temperature. These high discrepancies in salt performance will help the students to realize that as people have opposing behaviors, salts have can have a similar one. The word behavior will become a common term as it usually used in social and human science. This dynamic maneuvering between domains will help to stick the new concepts in the minds of the students.

Fluid viscosity is an important property for fluids. Introducing it to students as the proportionality constant between shear stress and velocity gradient is hard to grasp by students unless being simplified and connected with another physical phenomena like flowability and friction (macro scale), as illustrated in FIGURE 17. Explaining the mathematical definition without building an intuitive feeling based on real observation will be a waste of time.

FIGURE 16
SOLUBILITY BEHAVIOR OF SALTS

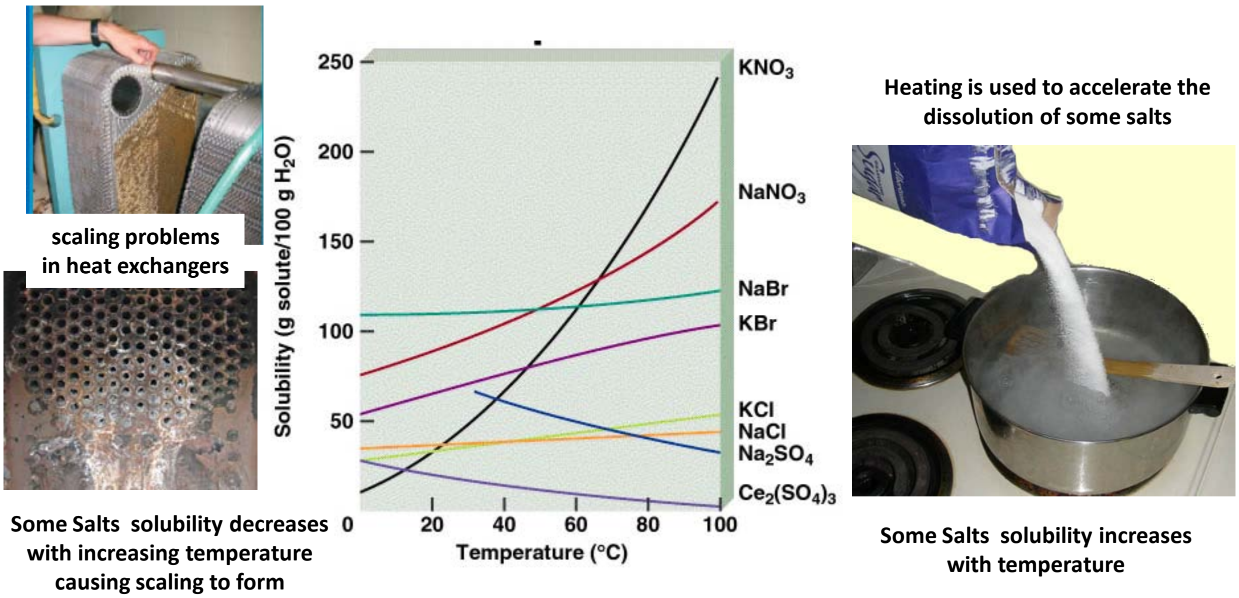
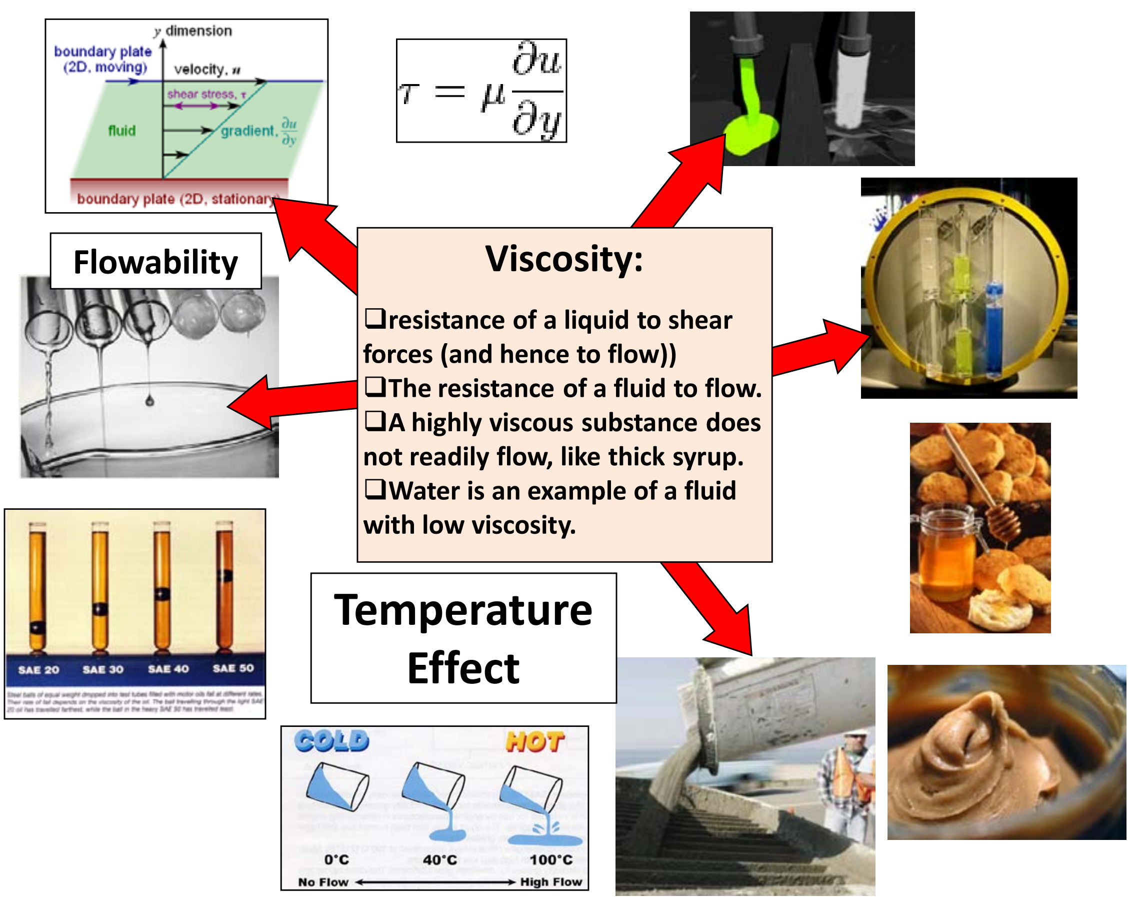


FIGURE 17
VISCOSITY OF FLUIDS

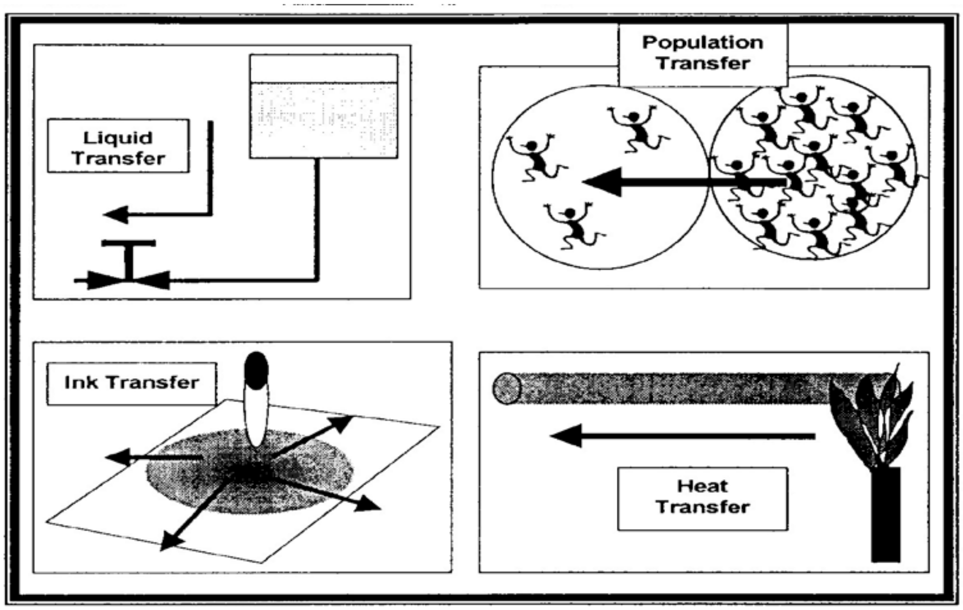


TTA Application in Engineering Education: Transparent Engineering Education

Transport phenomena are one of the core concepts in engineering sciences. Momentum, heat, and mass are the three important entities that engineers mainly deal with their transport behavior. Before dealing with any of these transport phenomena, it is important to break the barrier between the student and the transfer concept by creating intuitive feeling of the transfer process by dynamically maneuvering between more than one domains of use. As illustrated in FIGURE 18, Intuitive feeling of the transfer concept in terms people migration, liquid flowing out of a tank, diffusion of a dye in a piece of cloth, and transfer of heat in a metal wire contacted a flame from one side are an effective preparation for students minds to assimilate the higher level concepts that the student needs to construct mentally in later stages. Intuitive simple, connected and deep understanding of any concept is the infrastructure for building higher level abstract concepts through:

1. Conducting relevant and simple experiments that create meaning through student-environment interaction.
2. Dynamic maneuvering between domains to creative multi-perspective notion of the studied concept

FIGURE 18
TRANSFER PHENOMENA IN DIFFERENT CONTEXTS



Understanding the three basic types of physical transport phenomena by creating a mental construct that join them under one umbrella is of a paramount importance. Achieving the goal of deep understating of transport phenomena by employing our daily experience is leading us to the process of making tea. This daily experience comprises: momentum transfer in terms of mixing process done in the cub of tea; mass transfer in terms of diffusion of tea extract inside the solution; and hear transfer in terms of heating water. This simple and real-life examples and activities will be the sparkle that will initiate the process building the conceptual structure of transport phenomena.

One of most important failure symptoms in education is that teachers are neglecting the crucial importance of prior knowledge and experience that the students already attained before enrolling in any course. Bridging any existing gap between the student past experience and course material minimum required experience will immensely enhance understanding of the topics covered in any course. Employing simple and real life examples is an essential effective practice in bridging the gap in experience before delving in covering the higher level and abstract notions. As illustrated in FIGURE 19, boiling egg is implemented as a vehicle to help student acquire a deep understanding of the two important mechanisms of heat transfer (Convection and Conduction). Analyzing the whole modes of transfer in parts of boiling pan will help the student the skill for differentiating between these two important mechanisms of heat transfer through studying a real life activity practiced weekly in the kitchen.

FIGURE 19
HEAT TRANSFER IN BOILING EGGS

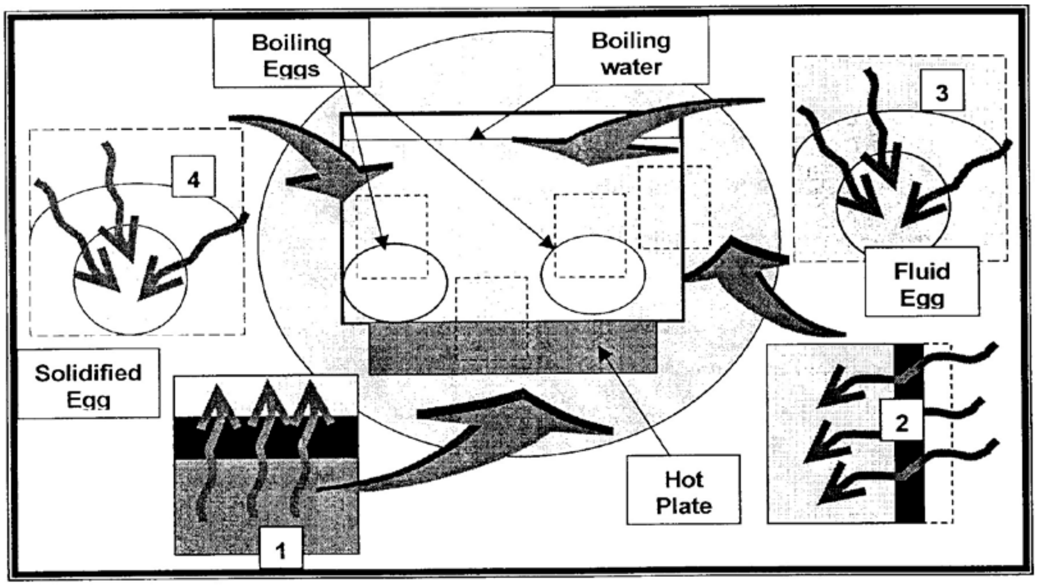
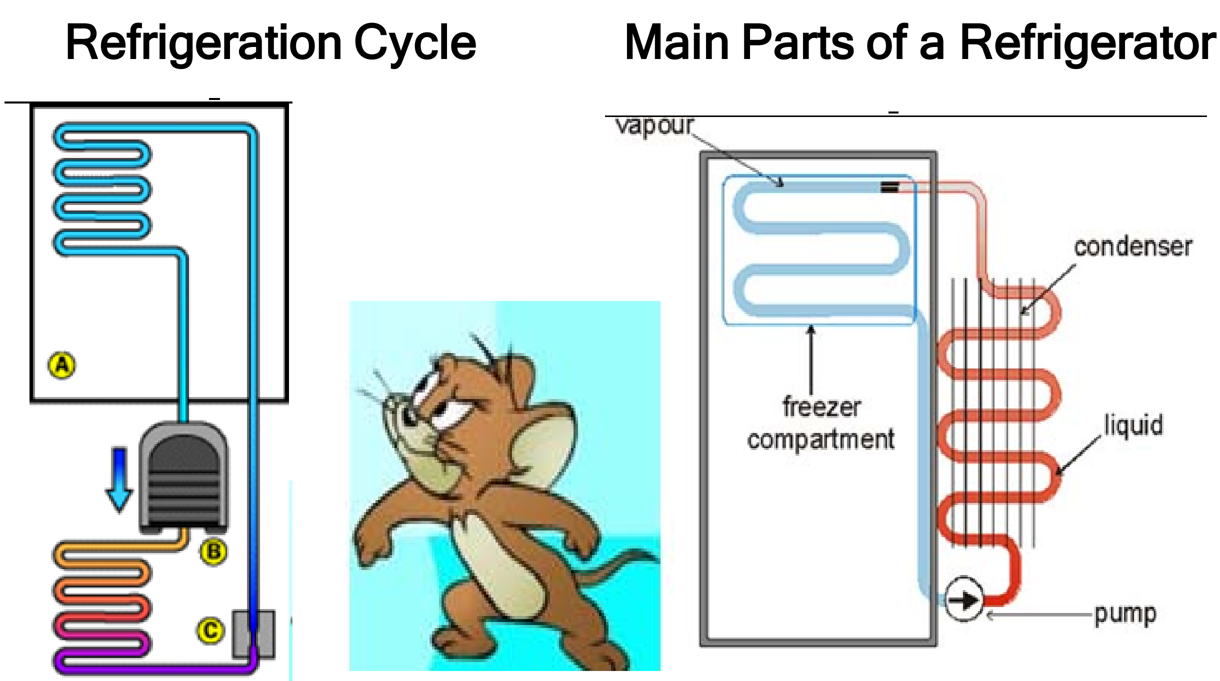


FIGURE 20
HOW MACKEY FEELS INSIDE A REFRIGERATION CYCLE?



Understanding deeply how refrigerator work is an important topic in engineering discipline (especially in Chemical and Mechanical Engineering). Helping the students to develop an intuitive feeling of what is going on in each stage of the refrigeration cycle is of paramount importance in helping engineering student to perform the calculation needed to study the performance of any refrigeration cycle. The author implemented Mackey as a cartoon character to help the students understand intuitively the different processes that occur in refrigeration cycle (compression, condensation, throttling, and evaporation), as illustrated in FIGURE 20. Also creating a clear connection between a real refrigerator parts and the refrigeration diagram will greatly help these concepts with their real life experience.

These are just few examples of a big library of transparent thoughts that are accumulated over ten years of university teaching experience and piloting TTA practical implementation.

TRANSPARENT CONCLUSION (TC): CALL FROM THE SOUTH FOR COLLABORATION

The desire to formulate an educational reform approach to reform Jordanian educational system was initially ignited 27 years ago (when I was a deeply feeling unsatisfied high school student). This deep feeling of unsatisfaction which is mixed with overwhelming desire to make educational reform was the impetus for the voracious effort to dig for an innovative solution for the stagnated and regurgitated educational system.

What is presented in this series of three articles is a conceptual framework for a big reform project that goes down to the micro scale (thinking level) to devise new way of thinking (TTA) and then extend this generic construct by coining transparization as an extended concept of learning. Transparent Learning (TL) diffuses to affect the whole educational system in the form of Transparent Education (TE). The propagation of transparency as a core instrumental value keeps diffusing to encompass any development or change process. Transparent Change (TC) is the widest frame that will gather all changes in this globe under one transparency umbrella.

The last 10 years of teaching and research at Chemical Engineering Department, Mutah University, was an excellent period for this new educational approach to evolve and fruit. It is believed that the dream that ignites the development of TTA approach is huge and needs a lot of efforts to be materialized. TTA approach is a micro scale change that extended and expanded to encompass all change processes in this globe. The encouraging and energizing responses from my students in Chemical Engineering Department, Mutah University, Jordan is the leading light for keeping motivation at the highest level.

I think that it is time to for this new approach to be established in the form of Transparent Learning Center (TLC). TLC will work as the incubator for implementing and disseminating this new approach. The writing of this series of articles aims at establishing the approach in the academic literature and can be considered as a call for international collaboration. It is expected that that way this new approach is presented was successful in conveying the basic TTA foundation conceptual construct and its applications.

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