"Tasting the Fruits" of Transparent Thinking Approach (TTA) by Developing and Validating a TTA-Based Solution Concentration Teaching-Learning Sequence (TLS):The "Kick-Off" of TTA Operationalization Phase

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In response to overwhelming global challenges, problems and failures, a Transparent Thinking Approach (TTA) is already conceptualized and customized and ready to be operationalized. This research is "kicking-off" the operationalization phase by designing, delivering and validating a Solution Concentration Teaching-learning Sequence (TLS). A TTA-Based TLS design framework (SRBF) is developed. The designed TLS is delivered to a sample of (n=28) randomly chosen chemical engineering students. The pretest confirms the urgent need to pedagogically and epistemologically reform the chosen solution concentration content knowledge. TTA-Based TLS was successful in enhancing the performance of the students. Student interviews result in collecting a valuable reflections.

INTRODUCTION: THE "KICK-OFF" OF TTA OPERATIONALIZATION PHASE

This paper is considered a continuation of publishing the outcomes of a big higher educational reform project that is called "Transparent Thinking Approach (TTA)" (Aliedeh, 2015 a, b, c, and 2016). TTA Project is a newly developed Values-Engrained and Thinking-Based Higher Educational Reform Approach that is conceptualized, customized and in process to be operationlized. TTA is planned to be accomplished through three phases: (1) Conceptualization Phase, (2) Customization Phase, and (3) Operationalization Phase, as illustrated in Figure 1 (A) (Aliedeh, 2016). These three phases cannot be sharply separated, because they are highly connected and have a hazy boundary that makes them interact, overlap and merge together. Conceptualization and Customization phases are mostly accomplished (Aliedeh, 2015 a, b, c, and 2016). The main objective of this paper is to "kick-off" the Operationalization Phase by developing, delivery and validation of a Solution Concentration TTA-Based Teaching-Learning Sequence (TLS). In his paper, the real "fruits" of this project will be "tasted" by "feeling" the innovative TTA created harmony between depth, meaningfulness, connectedness and simplicity which is reflected in the practical application of TTA concepts, tools, perspectives and constructs in a real settings. Before getting immersed in achieving the main objective of this paper, it is appropriate to tell the reader a short story that briefly revisit what is already accomplished in TTA Conceptualization and Customization phases and also to present new TTA insights that show how these two phases paved the road for the "fruiting" in TTA Operationalization Phase (Aliedeh, 2016).

TTA BRIEF STORY AND NEW TTA INSIGHTS

TTA Short Story: a Truly Unique Angle

Devising TTA as a new thinking-based educational reform approach is mainly initiated and developed to relieve the Global Crisis that overburdens Humanity. While seeking to trace the root causes of the educational system's problems, a two-way diving (maneuvering) journey is accomplished, see Figure 1 (B). In the first diving-in (discovery) part of the journey and by maneuvering between the specific (macro) and the generic (micro), it is found that Transparency is a stem and core instrumental value that can be germinated to create a new transparent thinking approach (TTA). In other words, TTA is seeded by this Transparency Discovery during the diving-in journey in the ocean of life. TTA helped in discovering that the root causes of our problems lies in our way of thinking and that thinking is engrained in deep value foundation (Aliedeh, 2016). Transparization and opaquization are the two new terms that are coined to physically represent the process of "black box" discovery that resembles our continuous knowledge discovery process, as shown in Figure 1(C). In analogy with Optical Transparency, a Generic Transparent Thinking (GTT) conceptual framework is formulated to help the TTA Thinker (Thinker that adopts TTA) to maneuver between different domains, disciplines, and fields, as shown in Figure 1 (D). Transparency is germinated from the base core value pavement and breeds to create a Hierarchy of Core Values, see Figure 1 (E). The TTA conceptual framework is divided into three major parts: (1) Core TTA, (2) Extended TTA and (3) Expanded TTA, and visualized in a form of physical model shown in Figure 1 (F) (Aliedeh, 2015 a, b, c, and 2016).

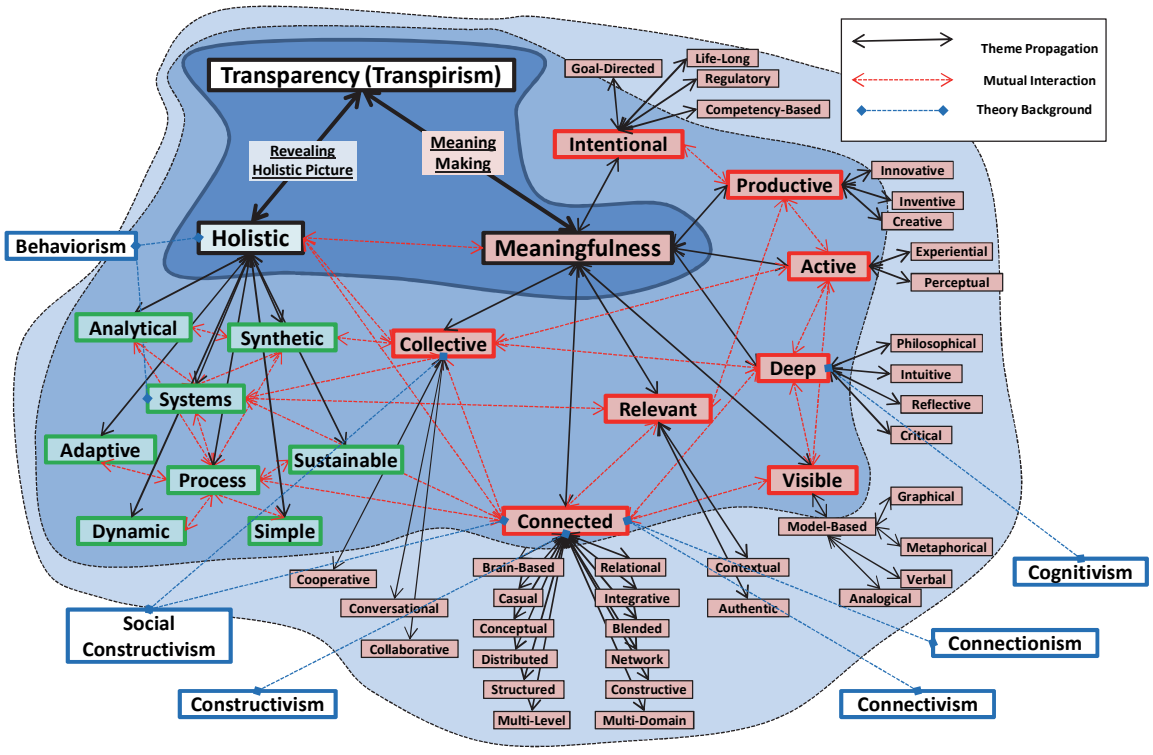
FIGURE 1
CONCEPTUAL GRAPHICAL EXHIBITION OF TTA SHORT STORY

As a part of TTA Customization Phase, three types of TTA toolboxes are established: (1) Generic TTA Toolbox, (2) Knowledge TTA Toolbox and (3) Work TTA Toolbox, as shown in Figure 1 (G). Generic Transparent Thinking (GTT) constitutes the core of TTA and is customized in the form of Generic TTA Toolbox which result in formulating an innovative form of Thinking-Based Learning (TBL). GTT is concisely defined as "the diagnostic ability of TTA Thinker to maneuver between different perspective and modeling tools with the supported of technology tools". TTA Thinker can generically think by maneuvering between domains, scales, fields, theories, approaches….. etc. GTT enables TTA thinker to maneuver from the Generic Thinking Domain to Knowledge and Work Thinking domains, as illustrated in Figure 1 (G and J). TTA thinker maneuvering in Knowledge and Work Thinking domains result in formulating a TTA knowledgeable and a TTA Worker, respectively, see Figure 1 (J). TTA Life Theater is considered the "factory" for knowledge production and work skills acquisition, see Figure 1 (H). TTA Life Theater is the platform where TTA Thinker can create and use new knowledge and work skills by implementing modeling, maneuvering, diagnosis, perspective and technology thinking tools. TTA Theater is equipped with Spots Lights (Thinking Perspectives) and supplied with a Modeling Stage (Learning Area) which are used by TTA Modelers, Learners and Teachers (Actors and Audience).

Based on the above developed tools and conceptual constructs, TTA is considered an innovative Value-Engrained and Thinking-Based knowledge and work skills production system that can be represented by a thinking tree. TTA take care of knowledge production from its core value roots till it developed into fruits, as illustrated in Figure 1 (I) (Aliedeh, 2015 a, b, c, and 2016).

Generic and Continuum Thinking Perspectives are at the heart of TTA conceptual construct and are also helping the learner to "breaks all barriers" by employing Transparent Maneuvering (TMv) Tools and creating multiple "Continuums" between: Transparency and Opacity, Genericness and Specificity, Different Modeling and Perspective Tools, Macro and Micro, Simplicity and Depth, Theory and Practice, Thinking and Work, Roots to Fruits, Value and Change, Past and Future, … etc.

FIGURE 2:
TTA PERSPECTIVES' PROPAGATION, INTERACTION AND THEORETICAL CONNECTIONS

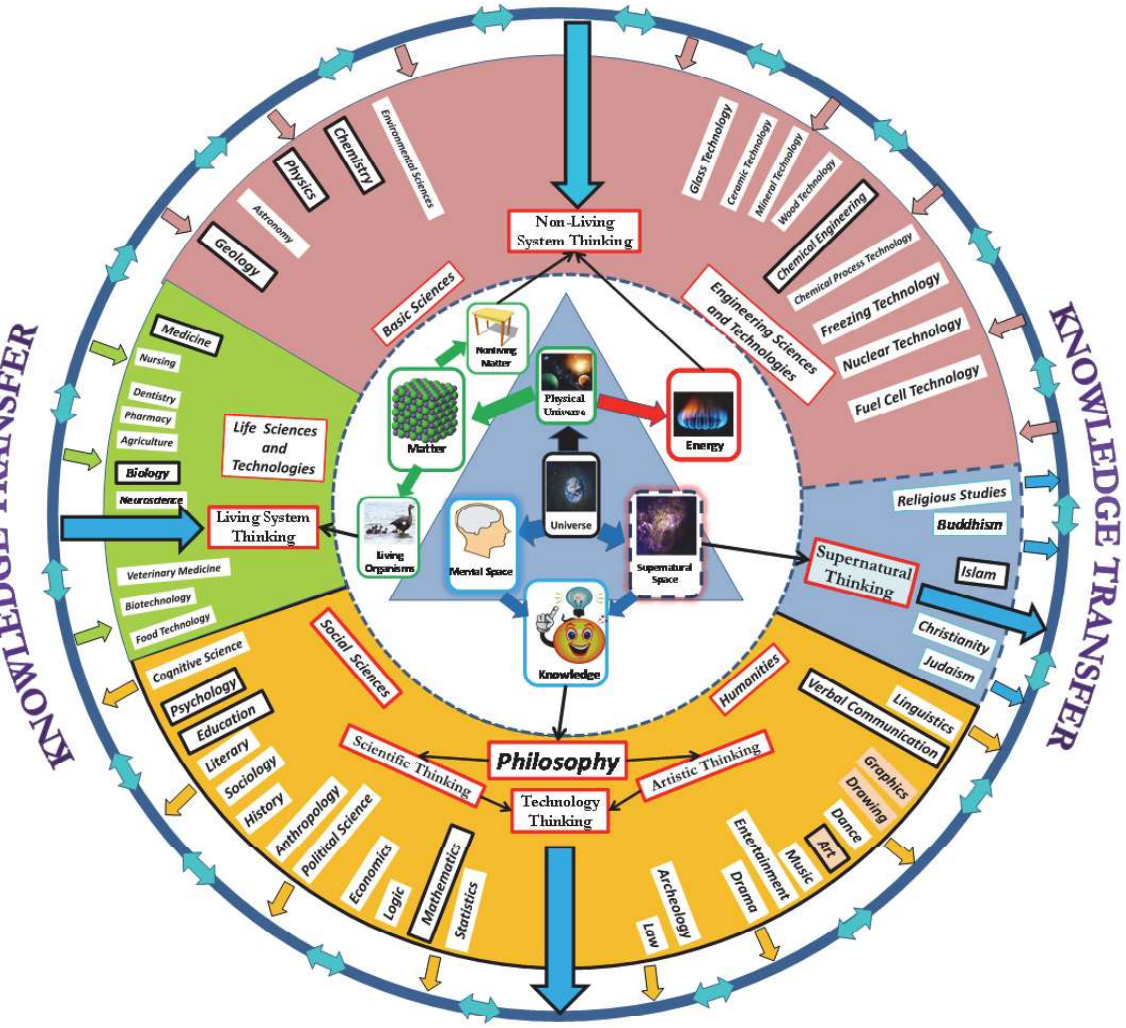


TTA themes and tools deeply affect the way TTA Thinker implements verbal and graphical modeling (Visible Modeling). TTA way of writing comprises an innovative mixture of graphical and verbal models that are merged together to create a new meanings. The TTA Way of Writing is characterized by "making graphics talk" while works in harmony with verbal language, as illustrated in this paper and the previously four published ones about TTA (Aliedeh, 2015 a, b, c, and 2016).

TTA Perspectives Propagation, Interaction and Theoretical Connections

TTA perspective tools are at the core of its conceptual construct and one of the important toolsets in the generic **TTA** Toolbox. Transparency perspective is a stem value that breads or prorogates in all directions to create a *hierarchy of multiple core values* as illustrated in Figure 2.These core multiple perspectives mutually interacted when projected into real contexts. The interactions between these perspectives create deeper meanings and more transparent holistic picture of entities that surround us in this universe. This clearly shows the richness and depth that characterize **TTA** as a "*change*" reform approach in its widest perspective as will be illustrated later in this paper. The evolving Transparent Learning Theory, that is represented by this structured hierarchy of perspectives, widened out to *accommodate* most of the existing learning theories, as illustrated in Figure 2. **TTA** is an *overarching* reform approach which has a wide spectrum of perspective tools that naturally work in harmony with other learning theories.

FIGURE 3
TTA INNOVATIVE VISION OF KNOWLEDGE TRANSFER



TTA Vision of Knowledge Transfer: Going beyond Grassroots Thinking

TTA diving "maneuvering" enabled us to get beyond grassroots level by getting to the seeds level that create these roots as will be implemented in **TTA**-Based Instructional Material design framework (see sections below). This critical seed locus and the developed Transparent Maneuvering Toolset enabled the **TTA** Thinker to "break barriers between all domains" and to uncover the *unity of knowledge* by showing the fictitious nature of knowledge disciplines and fields boundaries.

As illustrated in Figure 3, **TTA** thinker looks to the universe as made of three basic spaces (Physical, Mental, and Supernatural) and these three spaces produces three basic products (Matter, Energy, and Knowledge). Mental and supernatural spaces are mainly producing knowledge, but the physical space are mainly producing matter and energy. Knowledge is the most important product that is produced by the thinking process that occurs in the conscious spaces. Philosophy as the core discipline that humans devise to focus on thinking about the surrounding universe. Philosophy accommodates both scientific and artistic ways of thinking that are integrated to create technology thinking, see Figure 3. The *knowledge ignition triplet* (Science, art and technology) is responsible for the knowledge revolution that characterized the modern ages in the life of humanity.

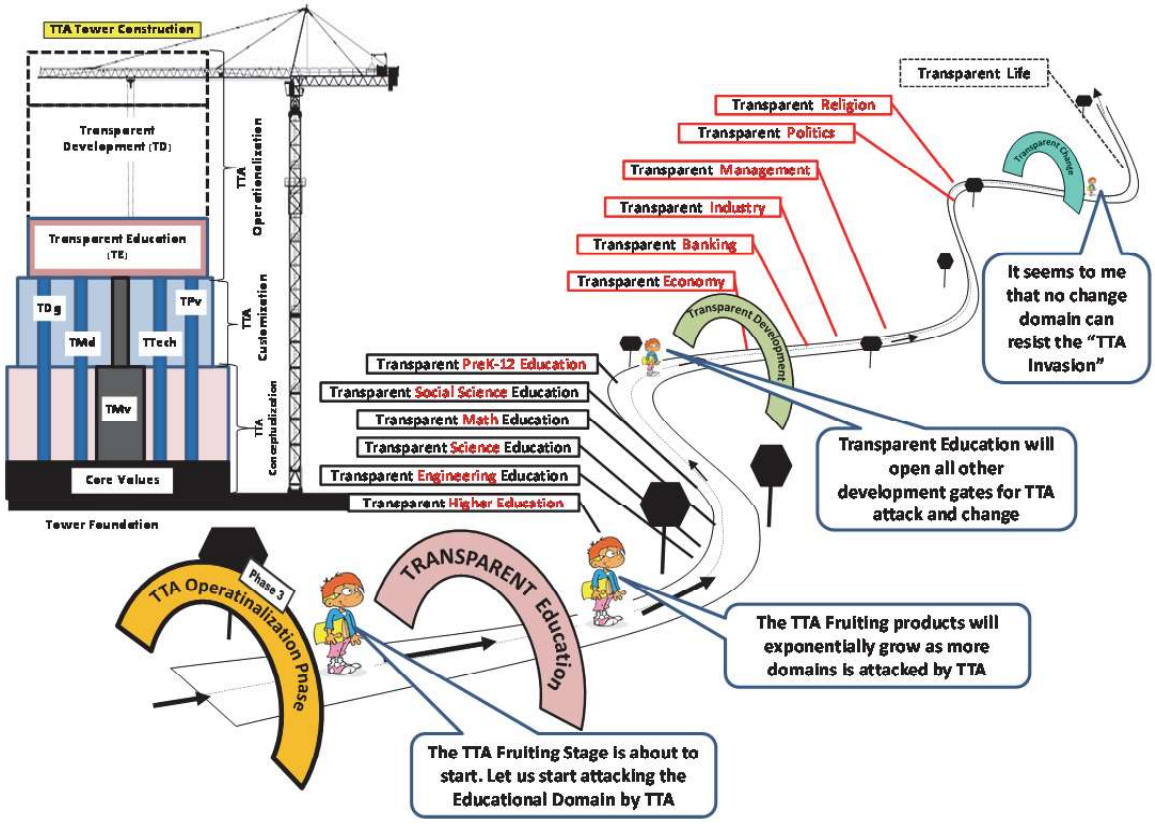
The strong trend of reductionism, that humanity indulges in, blinded us from seeing the big picture and result in creating compartmental knowledge by creating boundaries around each field and discipline. **TTA** sub-micro thinking result in devising a transparent maneuvering toolset that enable the **TTA** thinker to maneuver easily between the big and the small picture. Keeping thinking focus only on the holistic picture will create a kind of blindness that will hinder the thinker from zooming in to see the important details. On the other hand, keeping thinking focus only on the small details (reductionism) will create a similar type of blindness that will hinder the thinker from seeing the holistic big picture. **TTA** maneuvering toolset is equipping the thinker with the appropriate tools to dynamically change his focus as it is needed and to freely maneuver between scales, disciplines, fields, and domains. As illustrated in Figure 3, the two way highway of knowledge is open in both directions to connect all knowledge in all field in a harmonic and integrative way.

FIGURE 4
THE FIVE MAIN TTA PRODUCTS

TTA Renovation of Education

TTA is a *holistic educational reform approach* that targets first the learner to affect a *transparent way of thinking*. This *change in thinking pattern* needs a ***TTA*** *teacher* to help the learner in affecting that deep and genuine change. Both ***TTA*** *Learner* and ***TTA*** *Teacher* will be in need for a ***TTA****-Based Instructional Materials* to support their teaching-leaning process. The learner, the teacher and the instructional material need to be *accommodated* in **TTA**-Based *Learning Environment* and executed according to a ***TTA****-Based Protocols and Practices*. Therefore, **TTA** will *renovate* the educational process by *restructuring* and *reformulating* the five basic components of any learning process, as shown in a harmonic and integrative way in Figure 4. **TTA** learner is the most important product that should be kept under focus (marked by big red star). This does not mean that the other products are not important, but it means that they are less important and, at the same time are crucial in developing the most important products (**TTA** learner).

FIGURE 5
TTA OPERATIONALIZATION PHASE VISION'S ROAD MAP



Declaration of "TTA Invasion"

TTA, as a Value-Engrained and Thinking-Based educational reform approach with its value roots and thinking base structure, is basically able to "*diffuse*" in all development and change domains. The conceptualization of transparization as the *widest umbrella* to accommodate all learning processes enables **TTA** to be *inherently generic in nature*. The inherent genericness of **TTA** enables it not only to be just a new educational reform approach but also a development and change reform one, as illustrated in Figure 5. **TTA** is expected to build a strong base in educational domain that will eventually help to "*invade*" development and change domains. In the near future, **TTA** is expected to create a similar development version of **TTA**-Based reform approaches in banking, economic, industrial, management, social, religious and political domains, as illustrated in Figure 5.This is a "big dream", but its primary "*fruits*" started to be evolved. As illustrated in Figure 5, TTA Tower is under construction and TTA Operationalization stage is already started. A TTA comic character (will be called "Okla", arabic funny name), that is planned to be created in this phase, is hypothetically passing all the road and commenting on each stage of operationalization, as shown in Figure 5.

TLS DEVELOPMENT AND VALIDATION APPROACHES

TLS Development Approaches

During the 1980s and while seeking to develop a research-supported instructional materials, a trend in science instructional material design and validation research was formulated not based on developing whole curriculum (*Macro-level*) or specific session (*Micro-level*), but on specific topic sequence (Meso

level) for science teaching in areas like heat, optics, materials, fluids, photosynthesis and respiration (Méheut and Psillos, 2004).

Three approaches are mainly developed in later stages as *frameworks* for designing TLSs which are: (1) "Developmental Research" Approach (Lijnse, 1995)., (2) "Educational Reconstruction" Approach (Kattmann, et al., 1995) and (3) Learning Demand Analysis (Leach, et.al., 2002 and 2003). Lijnse (1995) introduced to European research community a "*Developmental research*" as a TLS development approach that is characterized by a rich collection of data and a cyclic evolutionary research process that accommodates and merges design, development and application of TLS. Kattmann, et al., (1995) introduced a TLS design framework that is based on "*Educational Reconstruction*" by implementing elaboration and improvement techniques (Méheut and Psillos, 2004). The learning demand analysis is based on a perspective that looks to science learning from an individual and sociocultural view of learning. Leach and Scott (2002 and 2003) confirms the central role that the teacher plays in learning demands analysis by presenting concepts to the class and also in guiding the classroom discourse.

TLS is considered as an *interventional research activity* that usually ends into a product. TLS is similar to any traditional curriculum unit package, but it is characterized by being well-researched and optimized *epistemologically* and *pedagogically*. This thorough TLS research-based optimization process usually includes research on: students' conception, specific knowledge domain features, epistemological assumptions, learning perspectives, pedagogical approaches and features of educational contexts (Méheut and Psillos, 2004). TLS design is developed based on a *gradual* and *evolutionary* research process that combines both scientific (*Epistemic*) and student (*pedagogic*) perspectives. The *Epistemic Perspective* (*Epistemic Constructivism*) is based on the determination of scientific method assumptions and the implementation of scientific knowledge elaboration and validation processes. The *pedagogical perspective* (*Psychological Constructivism*) plays an important role in the determination of choices of teacher's rule, types of interaction between teacher and students and between students themselves, students' conception of physical phenomena, and students attitude towards scientific knowledge. A trend is crystallized in TLS design towards an *integrated constructivism* in which *psycho-cognitive* and *epistemological perspectives* are merged together to work in harmony. Taking into account Méheut and Psillos four *didactical rhombus* corners (Students, material world, scientific knowledge and teacher) is the key factor in the successful TLS design (Méheut and Psillos, 2004).

Designed TLS Validation Approaches

TLS Validation of the designed **TLS** is mainly centered around two main approaches: (1) "*Production Engineering*" and (2) "*Experiential Research*". "Production Engineering" Approach is mainly focused on studying the feasibility and/or the effectiveness of the designed **TLS**. On the other hand, "Experiential Research" Approach is targeting the analysis of learning pathways and the underlying hypothesis. Both approaches are *complementary* and should *work in harmony*, because the TLS design process should aims to produce an instructional product and also to give us insights about the best design tools and validation techniques to be adopted in the cyclic and evolutionary **TLS** research process. Méheut and Psillos (2004) confirmed that there is *no contradiction* between the two perspectives (Productive vs. Experiential) and both should be accommodated within **TLS** research in a way to enable researchers to satisfy the requirements of both the *pragmatic value* (TLS as a product) and the *scientific validity* (Rigorous research-based TLS development).

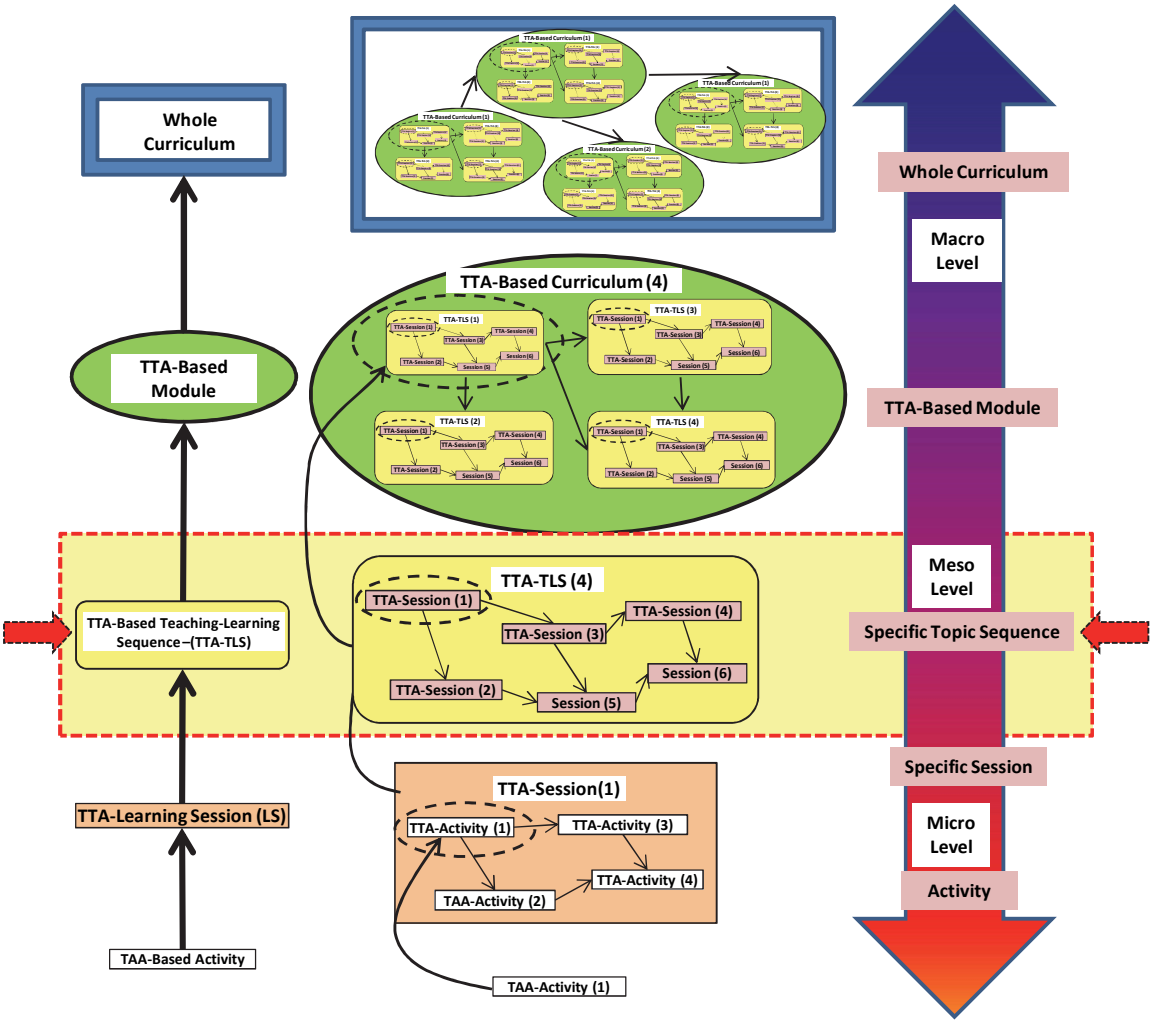
SRBF TTA-BASED TLS DESIGN FRAMEWORK

TTA-Based Instructional Material Hierarchal Structure

As explained above, TTA is a micro reform approach that is seeded in core value pavement and is based on a strong foundation of Generic Transparent Thinking (GTT). TTA wide, overarching and deep conceptual framework, unique angle, and its variety of thinking toolboxes make it capable to devise *its own instructional material design methodology*. The above **TLS** development and validation literature

review is not comprehensive because the focus in this paper is on implementing a new TLS design methodology based on a new reform approach (**TTA**).

FIGURE 6
TTA INSTRUCTIONAL MATERIAL HIERARCHAL STRUCTURE



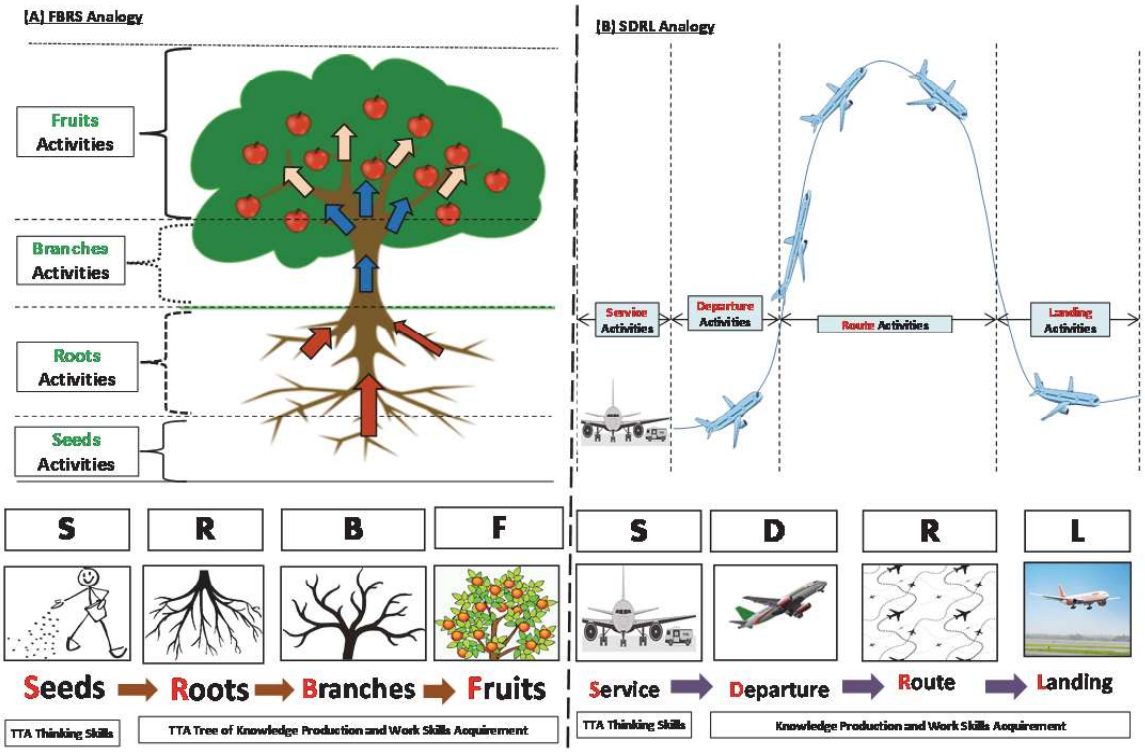
TTA instructional material design methodology is based on *hierarchal structure* of *instructional components* (*building blocks*) that spans the whole *instructional material size scale* by starting from micro level (**TTA** activity) to macro level (**TTA**-based whole curriculum), as illustrated in Figure 6. **TTA** activity is the micro size *instructional component* that can be grouped to create a **TTA** learning session which is then grouped to make a TLS. These components keep clustering or growing to eventually form a whole curriculum, as illustrated in Figure 6. TLS is located at the "*meso level"* of the **TTA** instructional material size scale.

Researchers in science education found that **TLS** meso size (median chunk size) is the most appropriate to be *pedagogically* and *epistemologicall*y experimented and reflected on. TLS is built out of a number of activities that is grouped in a number of learning sessions, and on the other side, it can be structured to create modules and whole curriculum. Successful TLS can be easily grouped with other tested ones to create newly developed modules that are structured to build a new whole curriculum (Méheut et. al., 2004, and Viiri, et. al., 2008).

SRBF TTA-Based TLS Design Framework

TTA is inherently based on the "*secret integration*" of *simplicity* and *depth*. This is affected in the form of effective implementation of *simple analogical modeling* tool to map relations between entities, phenomena and processes in different domains of life that the learners experience. Designing a TLS for a specific topic in a certain learning setting requires to start from a certain *knowledge locus* in the *content area knowledge structure* and then to go into a certain *route* till you get to the *targeted destination*. Therefore, three main groups of activities are needed: (1) Starting Locus, (2) Route and (3) Destination activities. **TTA** is also based on developing a new way of thinking that guides the learner through the process of acquiring new knowledge and works skills. A fourth group of **TTA** orientation activities is needed to precede the other TLS groups of activities in order to help the learner to switch to **TTA** mode of thinking before indulging into the trip in knowledge terrains. Therefore, four groups of activities are need to be sequenced. This sequence is initiated by **TTA** orientation, and then Locus and Route Activities till it is concluded by Destination Activities. In analogy, the four stages of activities is similar to an airplane trip that can be divided into four stages: (1) airplane service, (2) departure, (4) route flying, and finally (4) landing, as illustrated by Figure 7.

FIGURE 7
SRBF TTA-BASED TLS DESIGN METHODOLOGY

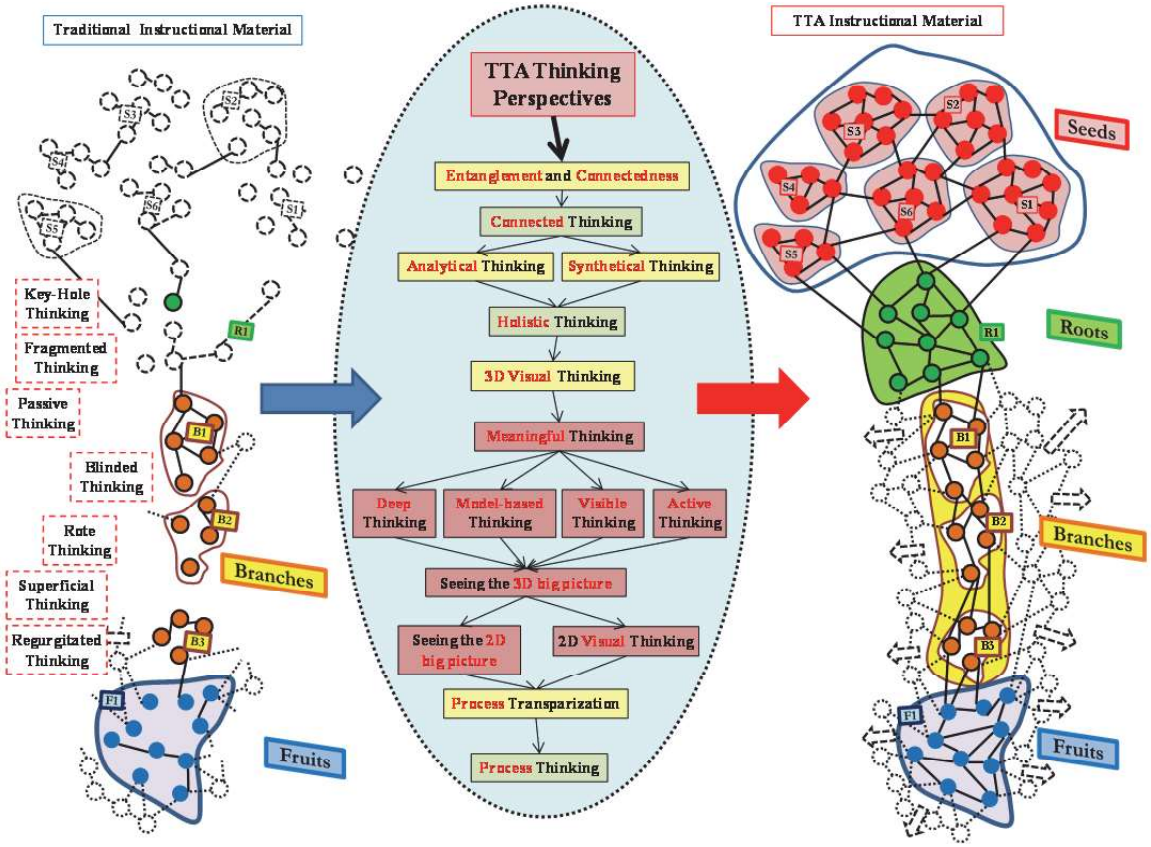


To deeply engrain the themes of the four stages of TTA-Based TLS sessions, planting a tree is used as a simple analogy to clarify the role of the four needed groups of learning sessions, as illustrated in Figure 7. Fruiting tree grows in four stages: (1) seeding and germination, (2) roots growing, (3) branches growth and (4) fruiting, see Figure 7. **TTA**-Based TLS designed activities are accordingly divided into four groups: (1) Seeds (Service) Activities, (2) Roots (Departure) Activities, (3) Branches (Route) Activities, and finally (4) Fruits (Landing) Activities, as illustrated in Figure 7.

TTA is based on building a **TTA** Thinker with new mindset, therefore ***TTA*** *Orientation (Seeds) Activities* are needed to prepare the learner to switch to this new mode of thinking in which he/she is leaning to "*transparize"* his/her experiences with the surrounding environments. The **TTA** orientation

activities can be considered as the seeds which *germinate* to grow roots, branches and then fruits. Once the learner is starting to grasp this new way of thinking, he/she should be ready to start the TTA-Based learning experience in three more stages : *Roots (Departure)*, *Branch (Route)* and finally *Fruits (Landing)*. As analogically depicted in Figure 7, the three groups of activities can be represented by the "*trip of nutrients"* from the roots to the fruits. The **TTA**-Based **TLS** should emanate from a departure point that represents the grass-root knowledge level. A route of learning activities should be chosen to connect the Roots group of activities with the Fruits ones. Based on the above analogical description, it can be concluded that TTA-Based **TLS** learning experience should be started by affecting a *mindset inclination* in learner mind to **TTA** thinking approach through TTA orientation activities and then the starting of the specific content knowledge learning from a roots point and then through branches till it gets to the fruits. This new TLS design framework is acronymed by "SRBF" TTA-Based TLS design Framework".

FIGURE 8
THE BIG STRIDE OF SRBF TTA-BASED TLS DESIGN



The Big stride of SRBF TTA-Based TLS Design

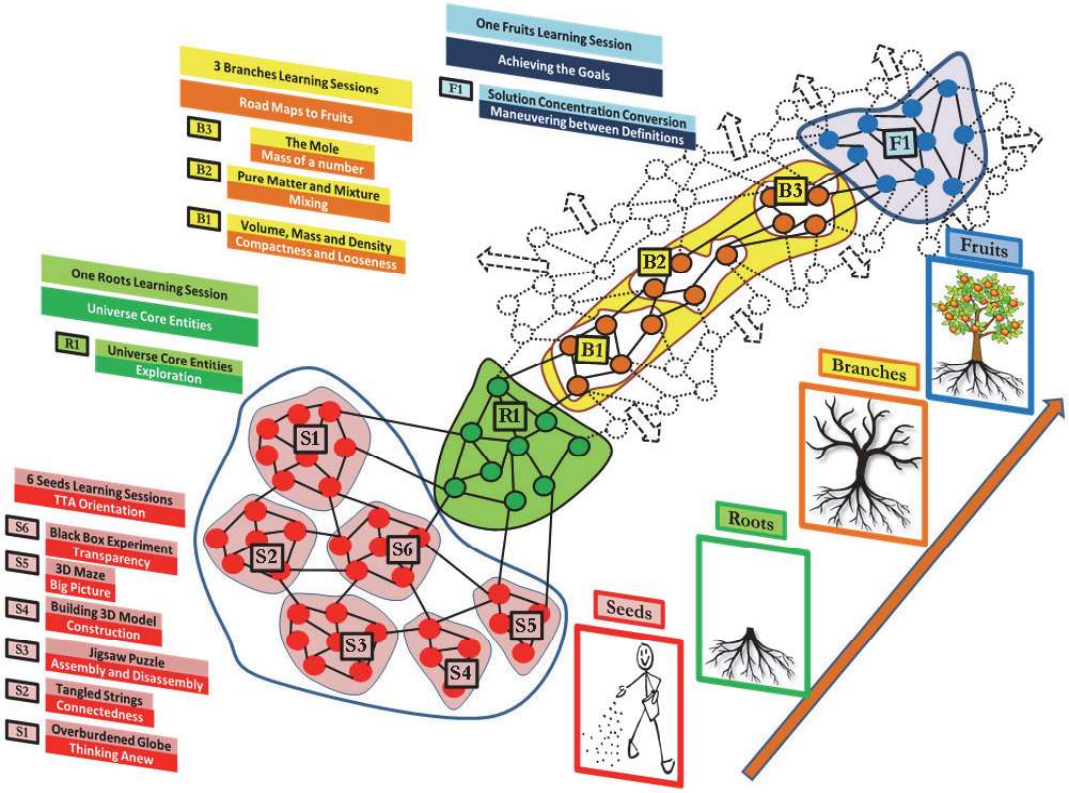
Traditional instructional material design suffers the dominance of keyhole, fragmented, blinded, passive, rote, superficial, and regurgitated mode of thinking that is reflected in an ill-structured and ineffective instructional material, as illustrated in Figure 8. TTA-Based instructional material design methodology made a big stride by making an *integrated paradigm shift* to connected, analytical, synthetical, holistic, meaningful, deep, model-based, visible, and active mode of integrated thinking that result in an instructional material that is "Structured to the bone", as illustrated in Figure 8. Traditional instructional materials are rarely taking thinking skills in their design perspective (Seeds Activities), and the reference point of departure is not usually included (Roots Activities). Traditional instructional

material is mainly reductionist in focus and concentrate on target topic activities (fruit activities) with weak linkage and coverage of perquisite concepts (Branch Activities). TTA-Based instructional design framework is deeply integrated and structured to cover the instructional material from seeds, and through roots, branches and till it reaches the fruits development stage, as illustrated in Figure 8. It is really a big stride that spans the whole route from seeds to fruits.

Storyline "Plot" of Solution Concentration TTA-Based TLS

Storyline or plot, as a literary term, is used to describe the sequence and connectedness of events that make up a story. These events is connected to each other in a certain pattern or a sequence. The story or novel structure depends on the organization of events in the storyline or plot of the story. In analogy with a storyline or plot, TTA-based TLS sequence of activities is designed and structured based on a similar storyline that starts from a knowledge structure locus and goes into a line of activities till it gets to the final targeted point of knowledge construction, as illustrated in Figure 9.

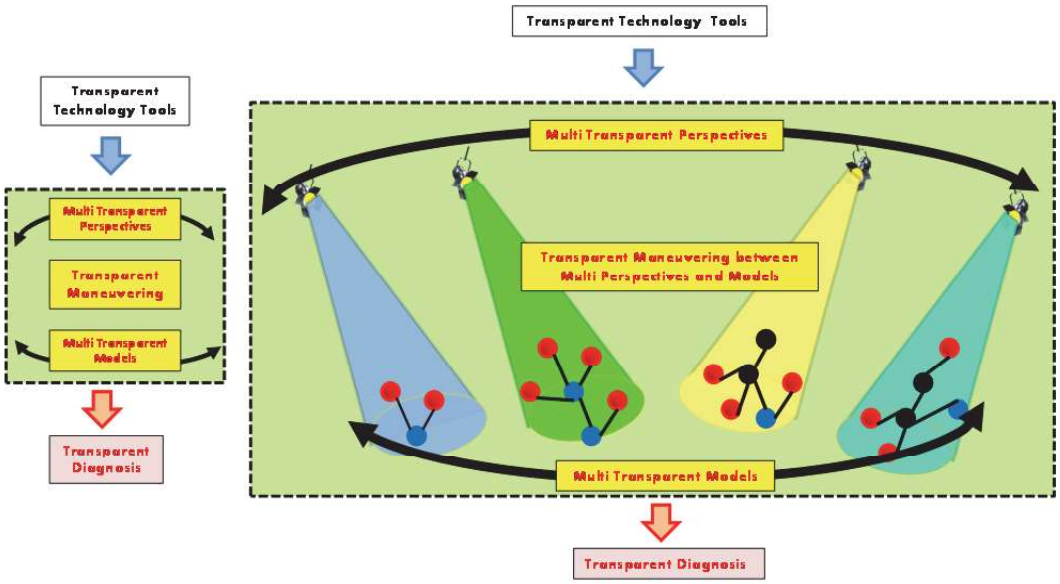
FIGURE 9
THE STORYLINE OF SOLUTION CONCENTRATION TTA-BASED TLS



In this paper, the story line is implemented in building a real example of Solution concentration TLS as will be described in details in later sections. The *Fruits Learning Sessions* in the designed Solution Concentration TLS learning story plot is to enable the learner to master the ability to convert between five different solutions concentration definitions: (1) Molarity (M), (2) molality (m), (3) mass fraction (m/m), (4) mole fraction (n/n), and parts per million (ppm). This main objective will be directly dealt with in the fourth stage in the form of a Solution Concentration Conversion Fruits learning session which comprises six activities, as listed in Figure 9 and will be described below in this paper. In TTA design methodology, preparing the learners with the needed background knowledge that enable them to acquire the needed targeted knowledge and skills is part of the vision that TTA-based TLS designer should include in his or her *blueprint layout* of the whole TLS story. Going backward in design, these *Fruits Activities* need to be

supported by appropriate perquisite concepts (Mole, Volume, Mass, and Density concepts) that will be covered through 3 *Branches learning session* which are essential for successfully accomplishing the *Fruits Activities* objectives. In analogy with the concept of physical frame of reference in physical sciences, the educational activities should devise a similar *knowledge structure frame of reference* and specify a *reference point* that all our knowledge and skills construction process is being referenced to it. In TTA-Based TLS design, the reference frame is represented by the *Roots Activities* which aims to establish the basic and fundamental concepts that all learners should depart from or retard to when needed. Once the Roots (departure) structure is established and the Branches (route) and the destination (Fruits) are determined, the learner will be in need to be equipped with TTA thinking tools that will enable him/her to pass the learning trip safely from roots to fruits. These TTA thinking tools will be covered through the Seeds learning sessions, as illustrated Figure 9. These four sets of learning sessions will be covered in more details in later sections of this paper.

FIGURE 10:
INTEGRATION OF TTA PERSPECTIVES AND MODELING TOOLS IN SRBF DESIGN FRAMEWORK



Implementation of TTA Perspective and Modeling Tools in SRBF TLS Design Framework

As stated before, TTA conceptual constructs was capable to devise SRBF TTA-Based TLS Design Framework based on the developed Generic TTA Tools. TTA-Based instructional material designer is able to maneuver between numerous TTA Perspective and Modeling Tools as illustrated in Figure 2 and Figure 10. This Maneuvering ability is one of the innovation secrets of the new TLS design approach.

Specific perspectives and modeling tools that are implemented in all the designed solution concentration TLS learning sessions are analyzed and the results is listed in Table 1 and Table 2.

This analysis shows the innovative way that TTA-Based TLS integrates multiple TTA perspectives and Modeling Tools in different contexts. The innovative harmony that is created by this collective interaction of all these modeling and perspective tools is one of the exceptional characteristics of SRBF TTA-Based instructional material design.

TABLE 1:
TTA PERSPECTIVE TOOLS IMPLEMENTED IN DIFFERENT SOLUTION CONCENTRATION TLS ACTIVITIES

Learning Session #	Meaningful Perspectives																															Holistic Perspectives							
	Connected												Intentional				Productive			Active		Deep				Visible					Relevant		Collective								
	Brain-Based	Casual	Conceptual	Distributed	Structured	Multi-Level	Relational	Integrative	Blended	Network	Constructive	Multi-Domain	Goal-Oriented	Life-Long	Regulatory	Competency-Based	Innovative	Creative	Inventive	Experiential	Perceptual, Sensual	Philosophical	Intuitive	Reflective	Critical	Performance-, Video	Scheme-Graphical	Physical	Analogical	Verbal	Contextual	Authentic	Cooperative	Conversational	Collaborative	Analysis, Mathematical	Synthesis	Systems	Dynamic	Process	Simple	Adaptable	Sustainable
S1	■		■		■		■	■	■		■	■	■	■						■		■	■	■	■	■		■	■	■	■				■	■	■		■	■		
S2	■		■		■		■	■	■		■	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■			■	■	■	■	■	■	■	
S3	■		■		■		■	■	■		■	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■			■	■	■	■	■	■	■	
S4	■		■		■		■	■	■		■	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■			■	■	■	■	■	■	■	
S5	■		■				■	■	■		■	■	■	■	■	■	■	■		■		■	■	■		■	■	■	■	■	■	■	■			■	■		■	■	■	■	
S6	■		■		■		■	■	■		■	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■	■				■	■	■	■	■	■		
R1	■		■		■	■	■	■	■	■	■	■	■	■				■		■		■	■	■		■	■	■	■	■	■				■	■	■		■		■	
B1	■		■		■		■	■	■		■	■	■	■				■				■				■		■	■	■	■	■			■	■	■		■		■	
B2	■		■		■		■	■	■		■	■	■	■	■	■		■		■	■		■			■	■	■	■	■	■	■	■	■	■	■	■		■		■	
B3	■		■		■		■	■	■			■	■	■	■	■		■		■	■		■			■		■	■	■	■	■	■	■	■	■		■		■	
F1	■		■		■		■	■	■		■	■	■	■	■	■		■		■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	

TABLE 2:
TTA MODELING TOOLS IMPLEMENTED IN DIFFERENT SOLUTION CONCENTRATION TLS ACTIVITIES

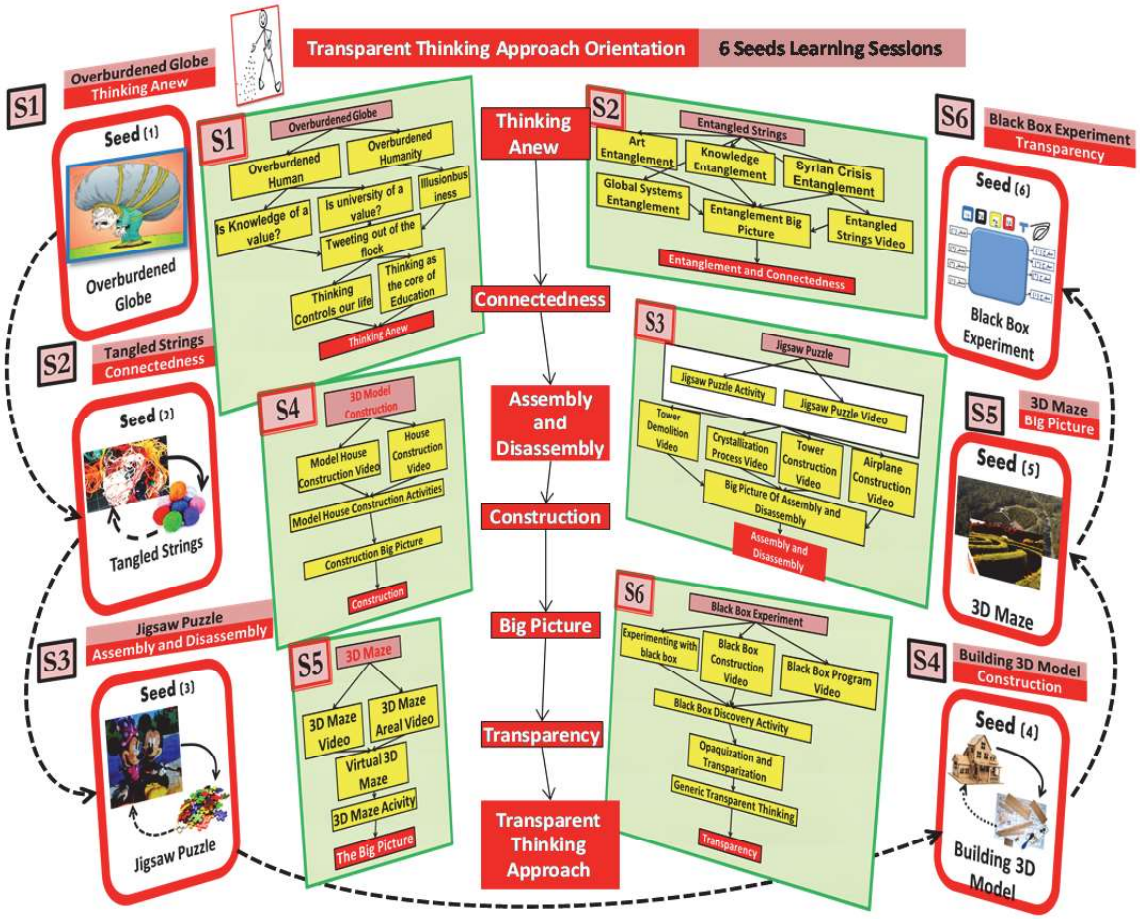
Learning Session #	Modeling Tools												
	Conceptual	Analogical	Graphical	Role	Video	Mathematical	Performance	Contextual	Cultural	Verbal	Physical	Intuitive	Process	Virtual
S1	■	■	■		■			■	■	■	■	■	■	
S2	■	■	■		■		■	■	■	■	■	■	■	
S3	■	■	■		■		■	■		■	■	■	■	
S4	■	■	■		■		■	■		■	■	■	■	
S5	■	■	■		■		■	■		■	■	■	■	■
S6	■	■	■		■		■	■	■	■	■	■	■	
R1	■	■	■		■			■		■	■	■	■	
B1	■	■	■							■		■		
B2	■	■	■		■	■		■	■	■	■	■	■	
B3	■	■	■			■		■	■	■	■	■	■	
F1	■	■	■	■	■	■	■	■	■	■	■	■	■	■

SEEDS LEARNING SESSIONS [S1-S6]

As mentioned above, the *Seeds Learning Sessions* (S1-S6) aim to help **TTA** learners to *restructure* their current mindset to accommodate and absorb the new ***TTA*** *way of thinking*. The six Seeds Learning Sessions are as follows: (1) Overburdened Globe, (2) Tangled Strings, (2) Jigsaw Puzzle, (3) Building 3D Model, (4) 3D Maze and (6) Black Box Experiment, as shown in Figure 11. Seeds Learning Sessions are offering thinking services for our learning machines (Minds) to equip them it with the necessary tools to maneuver in the knowledge construction and skill acquisition terrains. Seeds Learning Sessions are the largest in size when compared to Roots, Branches and Fruits ones, see Figure 9.

This indicates the importance of grasping the TTA way of thinking before getting immersed into the process knowledge construction and skill acquisition. Once the learner acquired the TTA way of thinking and grasped its tools, he/she will not be in need to study these sessions again in future TTA-Based TLS study.

FIGURE 11
TTA-BASED SEEDS LEARNING SESSIONS



Overburdened Globe Learning Session (S1)

As the first in a sequence of six *Seeds Learning Sessions*, Overburdened Globe (S1) aims to clarify to learners how the global community overburdens are triggering the need for new way of thinking. This session aims to introduce the learner to the hard challenges that are overburdening humanity and humans in person in these modern ages. Over long history, developing and developed countries built an *ill-structured relation* that is based on *illusion exchange business*. In response to global system being deeply

sunk in this harmful business, TTA thinker is tweeting out of the flock to send an *alarming message* of our need for new way of thinking. Current educational practices in developing countries are sending an alarming signals of absence or weakness of value in the educational system. This learning session will be ended by concluding that these challenging situations entails us to adopt a micro scale thinking solution that goes to the thinking core of the educational system in the form of TTA as micro scale solution.

FIGURE 12
SAMPLE PAGE OF OVERBURDENED GLOBE SEEDS LEARNING SESSION (S1)

Enhanced Form Serving Deep Content

TTA thinker believes that form should be employed to serve content, as illustrated in the sample slide of Seeds learning session in Figure 12.

This slide is divided into 6 areas: (1) Learning session title and short description area (Upper part), (2) Four quarters of display areas (3) Text description area (Middle). This way of presenting the material to student is similar to exhibition display in museums and art studios. This new way of chunking learning session into activities that is visually enhanced and displayed in an *attractive* and *appealing* way to the learner that usually encounter over the internet or the social media. Real life videos, pictures, graphics, concise and informative texts, hand-on activities, meaningful analogies and animations are integrated to create an effective TTA-Based learning material.

Tangled Strings Learning Session (S2)

In the 2nd seeds learning session, the themes of entanglement and connectedness are presented as an essential concept in the newly developed TTA way of thinking. *Tangled Strings* Learning Session aims to help the learner to connect the physical entanglement of strings with the real life *entanglements* (*Connectedness*) of domains, actions, events, parameters, variables, people, interests, knowledge …..etc. This learning session will be initiated by brainstorming about the high level of connectedness that is embedded in the surrounding universe. A brainstorming discussion will be initiated to deepen the concept that is already practiced physically. Each group of students will be given a group of entangled strings to detach and disconnect. While the learner is trying to analyze how these physical strings are entangled together, a strategy will be evolved to disconnect each string. TTA is inherently developed to help learners to "transparize" life by understanding, analyzing, and disentangling its complex connected components. This session will be a preparation for the learner for solution concentration conversion problem solving entanglement that will be practiced in the fruits learning session (F1).

Jigsaw Puzzle Learning Session (S3)

The third seed activities group centers around Jigsaw puzzle with a main theme of feeling the role of assembly and disassembly. *Jigsaw Puzzle Learning Session (S3)* main objective is to help the learner to deeply experience the physical meaning of *connectedness* by practicing building a *fragmented picture* into a *assembled one*. This session is in line with the tangled strings session in helping the learner to feel the importance of *connectedness* in creating meaning. The learners are asked to assemble the fragmented pieces while discussing the strategy that they develop while they searching for relations between jigsaw pieces and accompanied by formation of a mental image of the big picture. This activity enriches the learners experience while thinking of the whole universe as made of components that makes meaning when get together to create a collective structure.

Building 3D Model Learning Session (S4)

In this fourth seed learning session of activities which aims to give a chance for the students to practice building a 3D model with *construction* as a central theme. Building *3D Model Learning Session* (S4) is enriching the learner's connectedness concept by reflecting it in the domain of 3D model construction and visualization. The main objective of this session is to confirm the importance of connectedness in building a 3D mental image of the targeted disassembled 3D Model. The ability of learners to thing spatially while physically building a model will be enhanced as the model will gradually built. A discussion and short videos of house and model house construction will be displayed to the learners to show the importance of construction in the different field and domains of life and especially in the knowledge domain, as illustrated in Figure 11.

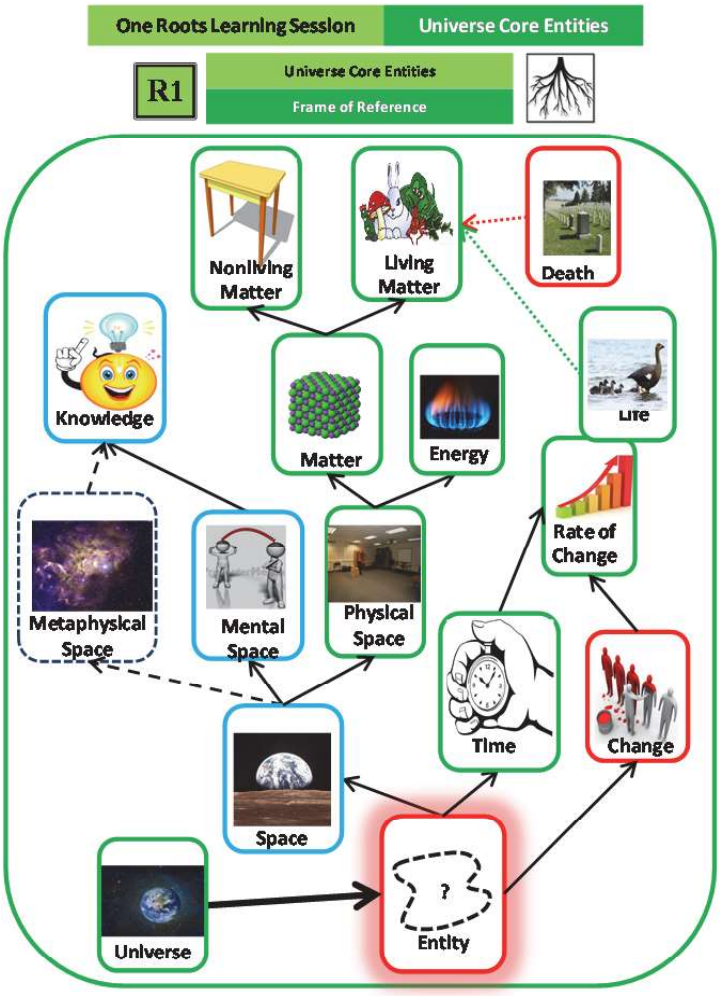
2D Maze Learning Sessions (S5)

In the fifth learning session of seeds activities, 3D maze activity is presented to students to help them intuitively understand the process of seeing the big picture. *3D Maze Learning Session* is very important experience that helps the learner to deeply realize the importance of *visualizing the big picture* of the whole puzzle while searching for his/her way out of this 3D maze. A two video clip that shows an actual park maze and how visitors are having fun while trying to find their way out of this maze. Students will be asked to virtually practice a similar experience using one of the online websites. Learners will be given a chance to solve a simple game of *2D Maze* that will helps them to feel the importance of acquiring the proper strategy to find their way out of a maze by building mentally a tentative road map for the way of passing through the maze from entrance to exit. *Dynamic Thinking* is implemented to help the learner to make changes in the tentative road map while passing through the maze. The tentative road map is a form of big picture that will help the learner to envision what is laying ahead.

Black Box Learning Session (S6)

In this sixth and last seeds learning session, a black box experiment is implemented to help the students understand the importance of transparency. This group of activities is the overarching core value that gather all the core values that are practiced before in the previous seeds learning sessions (e.g. entanglement or connectedness, big picture, construction, assembly and disassembly). TTA Orientation activities is culminated by doing a real black box discovery experiments. A certain mixing process is build inside a black box and the learners are asked to use their induction/deduction capabilities to reveal the hidden details of the process inside the black box. In order to discover what is hidden inside this black box, water is injected in a number of inputs to the black box while the outputs is monitored. Understanding the dynamic interaction behavior between these inputs and outputs will "*transparize*" the connectedness and functionality of the black box process components.

FIGURE 13
ROOTS LEARNING SESSIONS



ROOTS LEARNING SESSION [R1]

After being oriented to **TTA** way of thinking, it is time for **TTA** learner to move to Roots learning sessions as the first stage in growing the TTA knowledge construction and skill acquirement tree. In analogy with physical system frame of reference, maneuvering in knowledge terrains requires developing

a similar *knowledge structure frame of reference*. The Roots learning session will focus on structuring the *universe core entities*. These entities are considered the reference point for structuring our knowledge in different domains and fields. It is also the "*safe haven"* when the learner feels lost in knowledge terrains and needs to retard back to basic entities while seeking truth. The Roots learning session (Departure Point) is crucial for the success of any future learning experience because it is believed that learning should start from a *seed* that germinate in a *conceptual crystallization process*. The *Roots learning session* will be the seed crystallization process that all other learning experiences will emanate from. These activities will be based on creating a *deep feeling* ("*gut level feeling*" or "*grass-root understanding*) of the core universe concepts. The depth to feeling will be affected by *maneuvering* between knowledge domains and by creating conceptual structure of relationships between concepts, as illustrated by Figure 13.

Universe will be the first root concept or departure point to start our life discovery journey. It is a journey of discovering everything around us. A two video clips is displayed to the learners. The first will be showing a virtual zooming out journey from a place of the earth till you get to the deep space. The first video clip will help the learners to visualize and intuitively feel how infinite and big is our universe and how small is our planet in this universe. The second video clip is a zooming in journey on the skin of a human hand to discover the micro universe that we struggle to discover. The learner will conclude that as humans we are living between the macro and the micro infinite ends, our discovery job is not easy at both ends.

While touring in our universe we encounter a lot of things, generate a lot of concepts, and discover a lot of phenomena. Animals, trees, micro-organisms, house, love, viscosity, energy, heat, airplane, virus, enthalpy, persistence, vector, gradient, happiness ….etc. are some these things, concepts, or phenomena that we encounter in our life and needs a term that can gather all of these under one umbrella. An entity, as a philosophic term, is used as the umbrella term that can accommodate all these things, concepts, and phenomena. This activity will clarify to the learner that the mission of humans on this earth is not easy because of the varied nature of the encountered entities in this universe.

Space is the first entity that we encounter. When we mention space, the physical form of it is directly comes to our mind. The physical space of a person's room is very important in determining the activities that can be performed inside. Our feeling of happiness when we move to bigger new house and when we start roaming happily in their big rooms, or when we go in a picnic to an open fields in which you can look in the open horizon, or when you go into art museum halls with all its empty space. This activity is trying help learners to feel intuitively the importance of physical space as an essential part of our life in this universe. Physical space is the container of all our activities. Or it can be said that that our universe is mainly a space.

In this session, the learners are also introduced to another important type of space that we also encounter which is the conscious space. This space is a place that accommodates mainly conscious processes. Consciousness is the state or quality of awareness, or, of being aware of an external object or something within ourselves. Conscious space can be either mental or supernatural. Some of us believe in supernatural conscious space, but all of us believe that our single and collective mental conscious spaces are responsible for the change that is affected in our life all over ages. The main product of conscious spaces whether mental or supernatural is knowledge. We strongly believe that the meaning of all entities in this universe is created in our mental space.

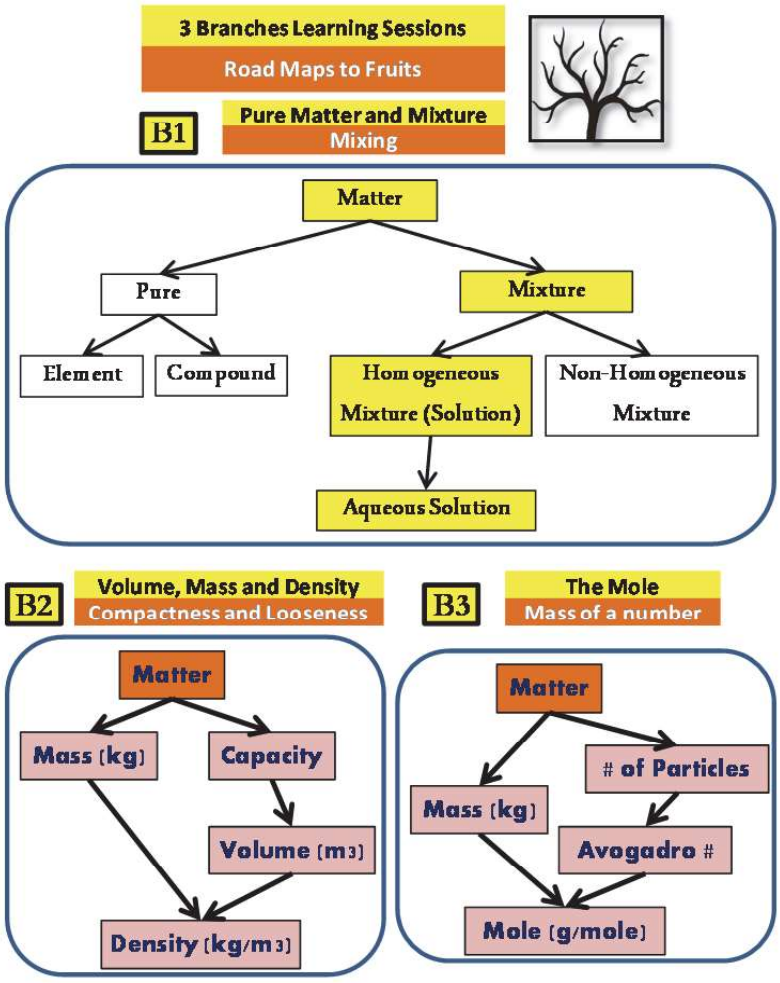
Physical space is usually filled with matter and energy. Matter is the physical substance that is contained in a certain physical space. Matter is either living or nonliving. Living matter is a physical matter with an added value of life.

Time is one of the basic entities in our life. Time is felt when we monitor change. Change is the widest overarching entity in our life. Building a house, having a shower, doing homework, human growth, tree fruiting …etc. are some of an infinite list of processes of change. Most of the time we are asking ourselves who clicked the timer to start change and who is able to stop it.

When the learner observes the living entities and compare it with non-living entities, he/she will be ask himself what is the added value that makes living entities grows, behave, interact and die. Some

disciplines (Engineering, Physics, Geology …etc.) are mainly deal with nonliving entities. On the other hand, other disciplines (Medicine, Biology, Botany …etc.) are mainly dealing with living entities. We getting astonished when we see a nonliving seed start to get life and grows to be a tree and then die to get back to be a nonliving logs of wood, or a baby born to grow to be a man and then at a certain moment it dies and get back to be nonliving matter. As shown in Figure 13, all these core entities are structured to form the core knowledge structure frame of reference. This reference structure be the point of departure while maneuvering in knowledge terrains.

FIGURE 14
BRANCHES LEARNING SESSIONS



BRANCHES LEARNING SESSIONS [B1-B3]

At this point, the learner are expected to be familiar with the TTA way of thinking and has structured the core universal concepts reference structure and ready to start the trip in a previously chosen route towards the fruits (Destination) concepts. Branch activities are the connection between the roots and the fruits. The process of clustering concepts will emanates from roots activities core concepts and goes on till it gets to the fruits activities. As shown in Figure 14, the first branch learning session (B1) discuss the structure of matter in terms of being pure or mixture. The main theme in this group is the homogeneous mixture. The 2nd Branch learning session (B2) covers the concepts of volume mass and density which are introduced with the theme of compactness and Looseness. In the third branch learning session (B3), the

concept of mole and molar mass with the theme of mass of a number of particles is introduced to students, see **FIGURE 14**.

Pure Matter and Mixture Learning Session (B1)

In this learning session, learners will be introduced the taxonomy of matter in which solution is part of the big picture. physical concepts are similar to "social" entities in terms of meaning making cannot be created in isolation. Solution is part of a bigger conceptual construct that creates its meaning. The Matter concept map is showing our understanding visibly and graphically and it is considered as an effective way of communicating understanding. Deep meaning is created by revealing how the solution concept fits in the bigger conceptual framework of Matter, see Figure 14.

Material can be either a pure material (one material) or a mixture (more than one material). Pure material are either an element (e.g. Iron(Fe), Copper (Cu), Aluminum (Al)) or a compound (e.g. Water (H_2O), Table salt (NaCl), Vineger (CH_3COOH)). When the material contains more than one substance it is called a mixture. Mixture is either homogeneous or heterogeneous. Homogeneous mixture is usually called solution. Solutions are characterized by being intimately mixed at the micro scale and the concentrations of any mixture constituent is the same all over the solution. In heterogeneous mixtures, the concentration of mixture constituents are varied at different locations inside the mixture. In this session, different visual material will be displayed to students to deeply understand the nature of type of matter (pure, mixture, homogeneous and heterogeneous) and the knowledge map of the whole collective relationships.

Volume, Mass and Density Learning Session (B2)

Volume is the scientific term that quantify 3D space. Students have difficulty in estimating volume, mass and density of materials due to the rote learning methodologies that they experience when they previously studied these concepts. Physical quantities and their units are not usually intuitively felt by students when they study they encounter these terms in their study materials. Therefore, the students are suffering the lack of deep meaning of these concepts and the absence of the intuitive feeling of their units of measurement as the pretest results shown in latter sections of this paper. This learning session aims to help the students to intuitively understand the deep concepts of volume, mass and density, in addition to the intuitive feeling of their units. Videos, graphics and hand-on experiments are used to covey the deep meanings and the intuitive feelings of these very important concepts, see Figure 14.

The Mole Learning Session (B3)

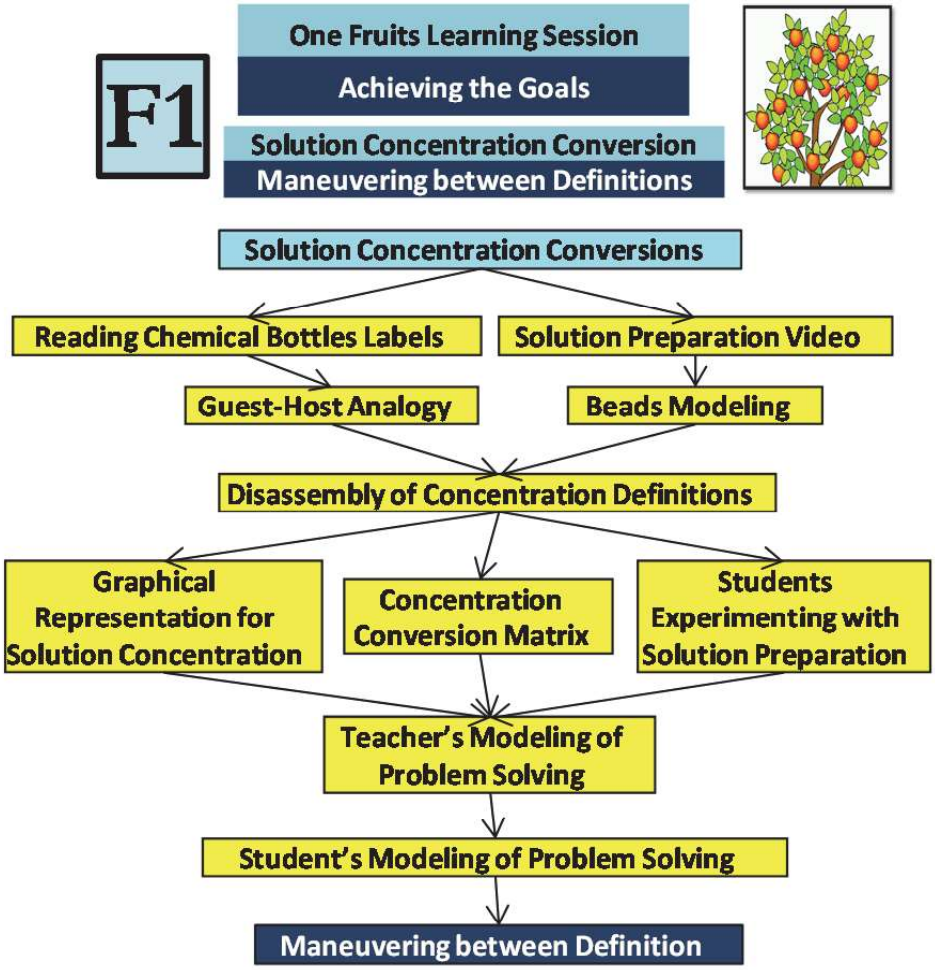
The mole concept is a very important basic scientific concept. Its relation with mass, number of particles, and molar mass is frequently superficially memorized as the pretest result shows in later sections in this paper. This session aims to help students to deeply understand the concepts of mole as a mass of a number and its relationship with Avogadro's number and molar mass. Simple and intuitive examples is employed to help the students deeply understand the mole concepts and its intimate connectedness with mass, number of particles and Avogardro's number, see Figure 14.

FRUITS LEARNING SESSION [F1]

When the students get to the fruits learning sessions, it means that they are already grasped the basics of transparent thinking (Seeds Activities), started their knowledge construction trip from the universe core concepts (Roots Activities) and passed successfully the three perquisite concepts (Branch Activities). All the above three groups of activities (Seeds, Roots, and Branches) are preparing the TTA Learner for the final stage and the fruiting of the previous effort in achieving the main objective of the whole TLS in mastering the conversion between five different types of solution concentration definitions (Molarity, Molality, Mass Fraction, Mole Fraction, and ppm). Namely, The learner will be ready to indulge in the stage of fruiting (*Fruits Learning Session)* that aims to help the learner to master the conversion between five different concentration definitions .

The main theme of this fruits learning session is to help the learner to maneuver easily between these five different concentration definitions. Eight activities are designed in this stage which are as follows: (1) Laboratory Solution Preparation Video, (2) Reading Chemical Bottle Label, (3) Beads Modeling, (4) Guest-Host Analogy, (5) Fragmenting Concentration Definitions, (6) Solution Preparation Experiment, (7) Concentration Conversion Matrix, (8) Problem Solving Diagrams, (9) Teacher Improvised Problem Solving, (10) Student Improvised Problem Solving, as illustrated in Figure 15. These activities are structured in order to collectively interact to achieve the final goal of deeply understand the problem solving process of solution concentration conversion.

FIGURE 15
FRUITS LEARNING SESSION: SOLUTION CONCENTRATION CONVERSION



1st Activity: Laboratory Solution Preparation

The first activity in this fruits learning session is a video displayed to the students in which a technician is showing how a stock solution is prepared and how laboratory tools and techniques will be used to accomplish the job effectively. Solution preparation is shown to be one of the most important skills that laboratory technicians need to acquire and practice as a part of their daily routine work. This contextual modeling activity will motivate the student when he realizes the importance of solution concentration conversion skill in lab context.

2nd Activity: Reading Chemical Bottles Labels

In the second activity, different chemicals bottles is shown to the students that has a different types of labels. Each group of students will be given a certain bottle to read its label information to specify the composition and concentration of its contents (Essay in chemistry terms) then exchange it with the other groups. This activity may include a real or a video tour in one of the chemical laboratories to show them some of the chemical bottle labels and the concentration definitions that are used to express the specifications of these chemicals. Real or Virtual Life Modeling (Contextual Modeling) is an important modeling experience that will give a real meaning to solution concentration conversion process and also motivates learners to master this important skill.

Reading these concentrations in the labels of these chemical will help the student to be intentional in their thinking and to be motivated to target the goal of dealing with these different concentration units. It is an authentic experience that will help the student to maneuver between these different units of concentrations in a meaningful way. Actively experiencing the variety of concentration units in real context will prepare the student minds to actively engage in deeply learning the skills of concentration unit conversion. This activity will be accomplished collectively between the groups members which will add an interaction dimension to the learning process. Learning in a real context by using authentic tools creates meaning by connecting the student with the context and its authentic practices.

3rd Activity: Beads Modeling

The third activity is a beads modeling in which black beads is used to represent solute and white ones to represent solvent, and when they are mixed they will form a solution. This activity is considered a macro modeling and physical experience that will help the students to feel intuitively the main components of a solution. All solution making processes occurs at the micro scale and does not enable the learner to see by the naked eye how the solute intermingles between the solvent particles to form a homogenous solution. Therefore, learners should start their experience by macro-scale model in the form of two colored Beads. Two colored beads (e.g. white and black) are given to students to physically, intuitively and analogically feel the macro-scale feeling of the solution making process by mixing of two-colored beads. The intuitive feeling that is expected to be developed by learners when they deal physically with this manipulative will help to transfer a deep feeling of solution making process. It will help the learner to be introduced physically to three important entities which are solute, solvent and solutions.

Macro-modeling using beads will create a deep meaning by making physical sense of the dissolution process of the solute inside the solvent. The collective making sense process of the dissolution process through macro-modeling using beads will pave the road to mastering the multi step problem solving strategy in later stages. The analogy that is established will be a great mediator in building strong problem solving ability of the student. The process of physically experiencing the mixing of beads as a macro model is an active process that engage student to the solution making process. The experience gained by physically experiencing the mixing of beads as a macro model will make the solution making process visible and deepen the gut level feeling of the solution making process. This activity will be an important step in mediating the gap between the visible and the invisible.

4th Activity: Guest-Host Analogy

The fourth activity will employ the cultural "Bedouin" background of the students in the form of analogy between Guest-Host and Solute-Solvent relationships. A usual greeting expression is usually used by the host to welcome the guests by saying "*ya hala ya hala*" which translated to mean "you are welcome you are welcome". The guests respond by an Arabic expression saying "*al mhaly mai waly*" which is translated to mean "the host will not flee a battle" as a sign of being courageous. Two cultural salutation expressions will be used to encode and decode solute and solvent during the problem solving process. The *intuitive feeling* of three basic entities (Solute, Solvent, Solution) in the solution making process is deepened by implementing *culturally engrained analogy* in the form of a *Host-Guest* analogical modeling Activity. A video clip of the heads of *bedouin tripe* visiting another tripe in their

tents is displayed to learners in order to analogically map a relation between hosts as solvent, guests as solute and the whole gathering as solution. This video clip is engrained in the Jordanian students minds as part of their cultural background memory that is acquired by practice or through local and drama series and movies. These two strongly engrained expressions will be used as a code between teacher and learners to guide the learners when they mistakenly exchanged in their concentration the solute with the solvent and vise versa. Cultural background is implemented in this activity to deepen and create an *intimate connection* between the learners and the three basic characters of solution concentration conversion process. This is a practical example of the use of *cultural mediator* in analogically creating a deep meanings of a scientific concepts.

The cultural analogy between guest-host social relationship and the solute-solvent relationship is very beneficial in transferring a deeply understood cultural process to enhance the understanding of a physical solution making process. The cultural analogy is deeply creating meaning by establishing this analogical connection and creating a deep gut-feeling and understanding of the solution making process and the relationship between its participants.

5th Activity: Fragmentation of Solution Concentration Definitions

After being motivated by *contextual, physical, analogical and cultural modeling*, the learning scene is ready for introducing the five different definitions of solution concentrations (Molarity, Molality, mass fraction (m/m), mole fraction (n/n), and parts per million (ppm)). These five definitions is fragmented into 10 basic constituents which are: (1) moles of solute (n_A), (2) mass of Solute(m_A), (3) molar mass of solute(M_A), (4) moles of solvent (n_B), (5) mass of solvent (m_B), (6) molar mass of solvent (M_B), (7) moles of solution (n_{Sol}), (8) mass of solution (m_{Sol}), (9) volume of solution(V_{Sol}), (10) density of solution (ρ_{Sol}), these constituent are illustrated in FIGURE 16. Each student will be supplied with the five concentration definitions and its 10 constituents each printed on a separate card board. Using these cards, the learners will practice analyzing and synthesizing these different definitions while comparing and contrasting them in an assembly disassembly activity. By the end of this activity learners should be able to recognize the five concentration definition, and assemble and disassemble them using their 10 constituents.

6th Activity: Solution Preparation

After accomplishing the previous five activities, the road now is paved to experience the real solution making process in an authentic experience. The students are given the chance to acquiring a real and authentic experience by dealing with real solute and solvent and practicing the use of the needed laboratory techniques. Acquiring laboratory techniques for making solution is an important active learning process. Dealing experimentally with real solute and solvent and learn how to make a solution from them is a great meaning making experience. The collective experimental solution making process will greatly enhance the students' understanding by their mutual interaction during the collective learning process. The different groups of students are asked to conduct a real practical experiment to prepare a solution with a certain concentration value and unit. This experiential experiment will help to introduce the students to the practices that is used in preparing a stock solution. At this point, learners will be ready for experimenting (Experimental Modeling) with real solutes and solvent (e.g. Table Salt (NaCl) and water). Learners are asked to conduct an experiment to prepare certain solutions with a given values (e.g. 5 Molar NaCl solution, 500 ppm NaCl Solution). Learners will be supplied with the appropriate laboratory equipments and glassware to conduct these solution preparation experiments, such as Lab. Scale, Volumetric Flasks, Pipettes … etc. This activity will culminate on contextual, analogical, experiential, and graphical modeling activities that are accomplished before.

7th Activity: Concentration Conversion Matrix

Suppose a family bought a new house and they moved in to it. One of the usual things that this family do is to search all over the place and to look in each room, cabinet, attic, roof and drawer to discover the

details of the house. They *cannot go sleep* for the first day unless the discovery job is fully accomplished. Analogically, the *holistic modeling* in terms of seeing the big picture of Concentration Units Conversion is a very important skill for the **TTA** learners to perform before starting learning each concentration conversion separately. As listed in

TABLE **3**, five concentration definitions is under study in this TLS which result in 20 different concentration conversion cases. Even if 20 conversion cases is a big job to accomplish, knowing that they are "*only 20 and that's it*" will lower the psychological burden on the learner's heart by saying "Even if they are 20 cases, at least I know the size of the whole job which is better than practicing some and hiding the rest of them". Knowing the size of the job even if it is big is better that leaving the learner in confusion about where to start and where to end.

The holistic thinking in the form of seeing the big picture will ease the heart of the students concerning the size of the job that they need to accomplish. The big picture is getting visible by showing the all the 20 solution concentration conversion cases. Showing the 20 solution unit conversion cases in table form will make the goal completely clear so that any accomplishment will be easily quantified.

In this activity, a matrix of 5×5 solution concentration conversion will be presented to the students in order to show them that the whole job is to perform "just" 20 different cases of solution concentration conversion, as shown in Table 3. 20 cases of solution concentration conversion may seem "frightening" to students but actually the burden on students will be relieved because even because if they are 20 cases, the student once understand them he/she will have no fear because the whole full picture is revealed. Namely, showing the whole picture is not an overburdening experience to students, but on the contrary they will feel confidents that once these jobs are mastered, they can say confidently that we can do all the possible conversion routes and "nothing is hidden". Seeing the big picture may seem a burden on the short term vision, but it is "heart relieving" in the medium and long term vision.

TABLE 3:
THE BIG PICTURE OF THE CONVERSION CASES BETWEEN THE FIVE BASIC CONCENTRATION DEFINITIONS

From/To	Molarity	Molality	Mass Fraction (m/m)	Mole fraction (n/n)	ppm (based on m/m)
Molarity	2 M	Case (1)	Case (2)	Case (3)	Case (4)
Molality	Case (5)	5 m	Case (6)	Case (7)	Case (8)
Mass Fraction (m/m)	Case (9)	Case (10)	0.25 m/m	Case (11)	Case (12)
Mole Fraction (n/n)	Case (13)	Case (14)	Case (15)	0.75 n/n	Case (16)
ppm (m/m)	Case (17)	Case (18)	Case (19)	Case (20)	500 ppm

8th Activity: Problem Solving Diagrams

The learner's ability to solve multi step chemistry problems is greatly enhanced when schemas are used to aid in visualizing the road map of the solution. As illustrated by the example shown in Figure 16**FIGURE 16**, the case (1) is presented as an example of how the solution definitions and its elements cardboard are used to structure a solution diagram. This diagram explains graphically the calculation steps that the learner need to perform in sequence or parallel in order to come up with the needed results. As shown in Figure 16, the five different solution concentration definitions is written in coded form in terms of its constituents. This activity once practiced physically by arranging cards for few times, it will be directly transferred to be a mental process that will be accomplished in later stages without the need to do it physically by cards.

Implementing flash cards in a coding-decoding process of concentration unit conversion process is an experiential part in terms of building knowledge maps using the cards of solution constituents. The main characteristics of the concentration conversion coding-decoding process using flash cards are: (1) building knowledge maps by using flash cards to enhance the visibility of problem solving process by seeing the big picture, (2) helping the students to see the intermediate and final goals. (3) using the cards are

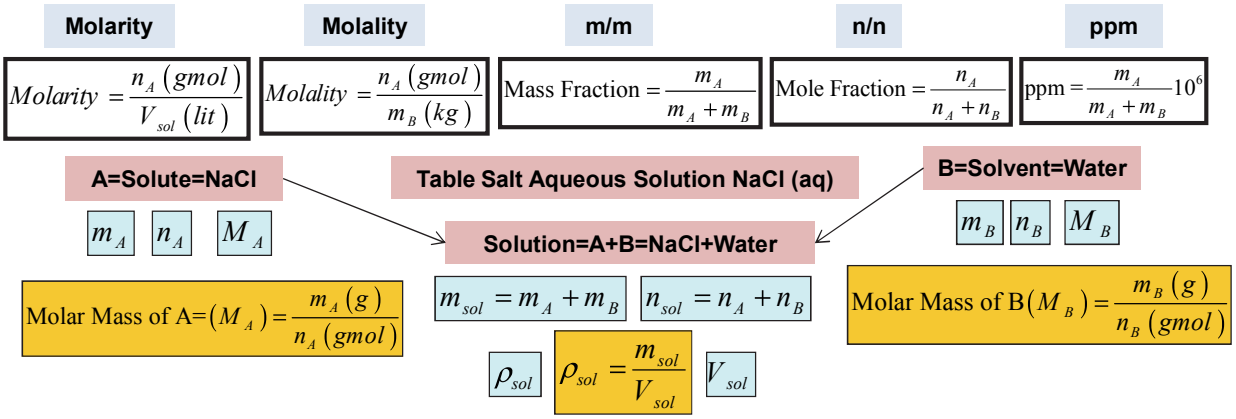
thinking tools to reveal the connectedness between the studied components, (4) actively engaging students in deep meaning making and problem solving process, (5) It is considered a practical implementation of model-based thinking.

9th Activity: Teacher Improvised Problem Solving

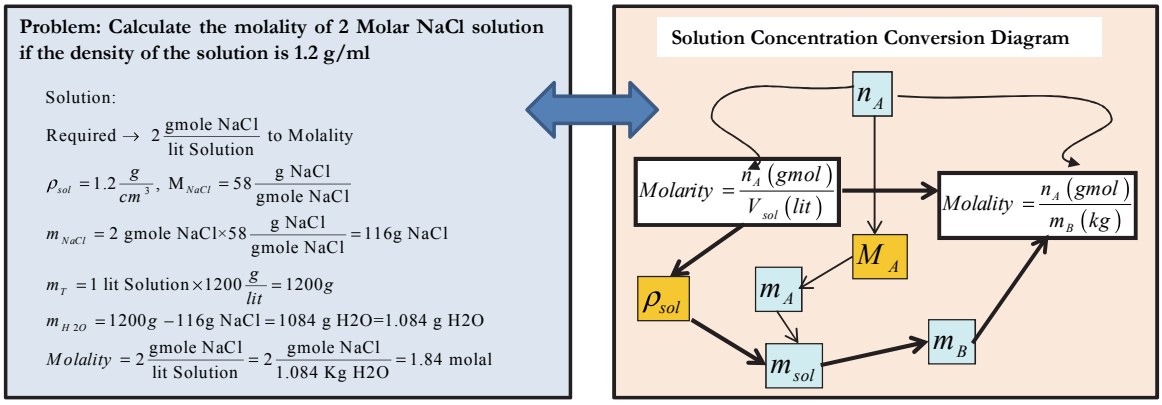
In this ninth activity, the teacher is ready to let the student choose a case randomly and then improvisely perform the calculation using the graphical problem solving diagram. The teacher's improvised detailed solution will be valuable in giving them a chance to see a live example of thinking a load. This will be help the students to reach the mastery point (courage) to deal with any problem of the 20 cases. Teacher improvised problem solving will help in making the teacher thinking process visible and will practically show to the students a thinking role-modeling in context.

FIGURE 16:
GRAPHICALLY ENHANCED SOLUTION CONCENTRATION PROBLEM SOLVING

(a) Fragmentation and structuring of Solution Concentration Definitions



(b) Implementation of Graphically Enhanced Solution Concentration Problem Solving Methodology



10th Activity: Student Improvised Problem Solving

At this point, it is time for the student to take the lead and try the teacher experience in solving concentration conversion problems in an improvised way. The students will randomly be given solution concentration cases (1-20) to solve initially collectively and then individually using the graphical representation problem solving diagram. The students will be given a chance to think aloud and to show their thinking approach in order to be critiqued by the other group member and the instructor. Collectively

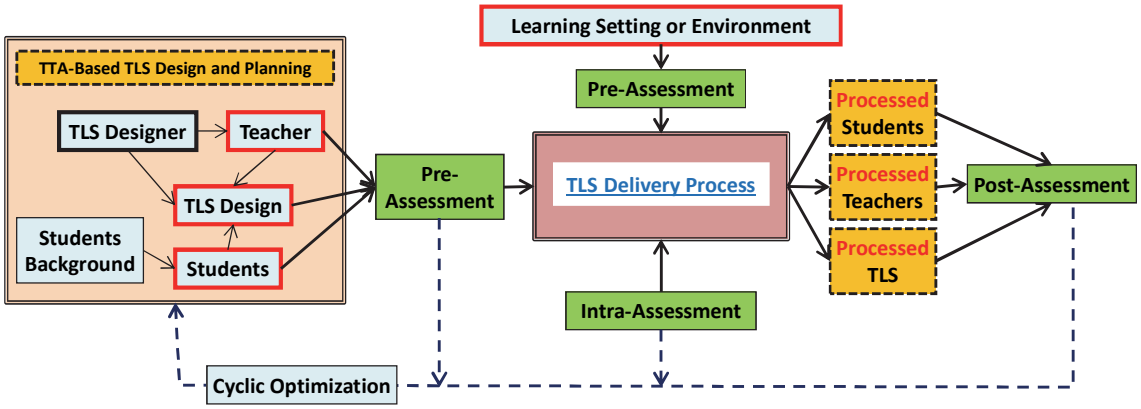
practicing thinking between peers will effectively enhance the interaction between students and eventually the learning process, and also will create a meaningful experience for all students in the class.

RESULTS AND DISCUSSION

Solution Concentration TLS Validation Strategy

The designed Solution Concentration TTA-Based TLS is described and ready to be validated. The proposed TLS design and validation process is iterative with feedback loops, as illustrated in Figure17. The feedback loops are feeding the design and planning process with insights from pre, intra and post assessment checkpoints. The first step in this validation research is accomplished by randomly choosing 28 chemical engineering students from Chemical Engineering Department, Mutah University, Karak, Jordan. The chemical engineering students participated in a pretest, a workshop for the designed TLS, a postest and finally a videotaped interviews.

FIGURE 17
TTA-BASED TLS DESIGN AND VALIDATION DIAGRAM



The validation loop is initiated by preliminary design of a TLS, as illustrated by Figure 17. Then, a pre assessment for the sample student is conducted based on the designed TLS content. This assessment checkpoint will send feedback information, that are based on the analysis of the pretest results, to the designer to do the necessary modification in the content knowledge and the level of elaboration of each topic covered. In the case of the Solution Concentration TLS covered in this paper, the pre assessment (the pretest is listed in the Appendix) result analysis confirms that it is essential to include the two branches sessions (B2 and B3) that cover volume, mass, density and mole concepts, because of the low performance that students' attainment in these sections of the pretest (39% for density pretest and 61% for mole pretest), see Figure 18 (a) and (b) and Figure 19.

The pretest also confirms that chemical engineering students suffers a severe weakness in converting between concentration definitions(7% for concentration pretest) and this needs to be pedagogically and epistemologically reformed, see Figure 18 (c) and Figure 19.

At this point, the designer (author) confidently felt that the targeted concepts is appropriately chosen and there is a genuine need to produce TTA-Based TLS that can cover this gap. At this point, it is time for the TLS delivery which is executed in the form of 4 hour workshop in two meetings. By the end of this workshop a post test is conducted to the sample of chemical engineering student. After grading this post test, an analysis is performed to the results which show a very good enhancement in students performance (7% for Concentration pretest and 62% for Concentration posttest, 55% Concentration Improvement), see Figure 18 (a)-(d) and Figure 19.

Intra TLS delivery assessment is performed in the form of a video interviews with the students in the sample to give them a chance to talk about their experience in this TLS videotaped workshop. All these

different assessment tools are considered an insights collecting resources for more optimization of TLS design, delivery and validation processes.

Pre and Post tests: TLS Assessment of Sample Students

As explained in the Solution Concentration TLS validation strategy, pre and post test are essential (the Pre test is listed in the Appendix) to quantify the real change that is affected in student performance and consequently inform the TLS designer (author) about the effectiveness of his TLS. The analysis of pretest results show that students are urgently in need for a reformed instructional material in the targeted perquisite (branches domain) concepts (Volume, Mass and Density, and Mole) and the (fruits domain) solution concentration conversion problem solving strategy, as shown in Figure 18 (a)-(d) and Figure 19.

These pretest results motivate the author to work hard on designing a TTA-Based TLS that is able to fill this gap. As we know, these concepts are originally high school concepts that are repeated in introductory chemistry and physics courses and repeated again in basic principles of chemical engineering course. Therefore, the author was "shocked" why these basic concepts are not deeply transferred to the students minds in spite of being repeated more three times in different courses. The "well known" answer to this phenomena is that the coverage of these basic concepts are superficial and not intuitively ingrained and this result in the seepage of these loose concepts once left for a short period of time especially in developing countries where the pedagogical approaches are rote and blinded. Post test results shows that the designed TLS was successful in achieving a very good improvement in the covered concepts, as shown in Figure 18 (a)-(d). The great students appreciation for the newly designed and delivered TTA-Based TLS was a sign that this new approach hit a string in their hearts as will be discussed in next section.

FIGURE 18:
COMPARING THE PRE AND THE POST TEST RESULTS OF SAMPLE CHEMICAL ENGINEERING STUDENTS

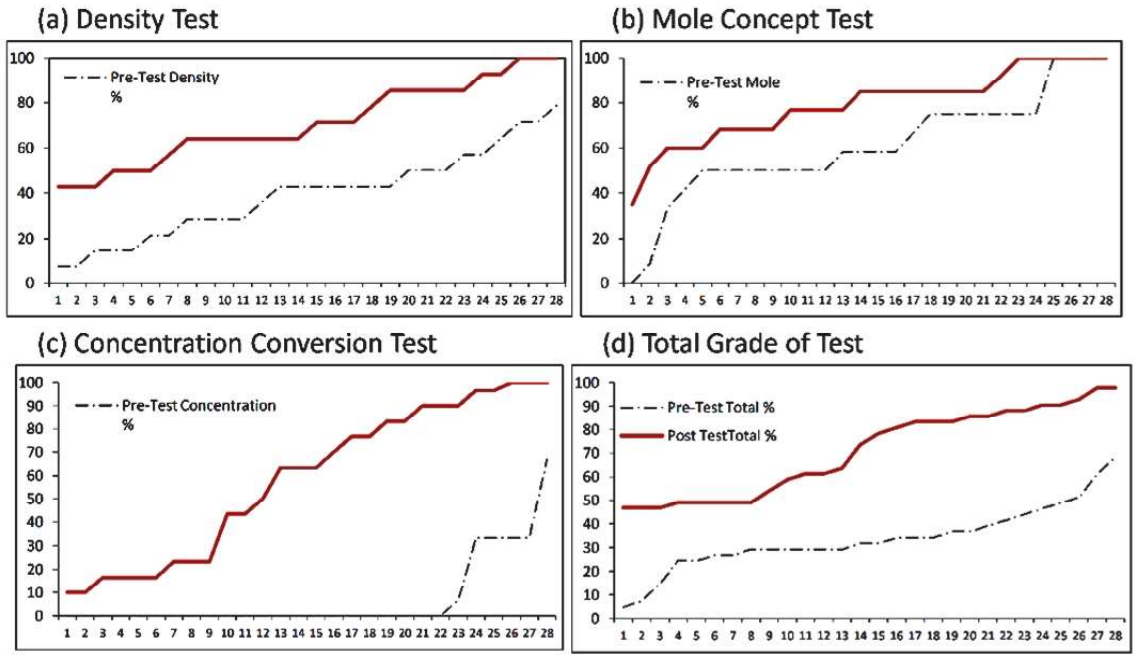


FIGURE 19:
CALCULATION OF PERCENT IMPROVEMENT (BAESD OR REATIVE AREA CALCULATION) IN STUDENT PERFORMANCE BASED ON TLS PRETEST AND POST TEST

Test Topic	Pretest	Posttest	Improvement
Density	39	71	32
Mole	61	79	18
Concentration	7	62	55
Total (All three topics)	34	71	37

Students' Interviews: Insightful comments from students

Paper pre and post test is not the only source for providing insights for the educational researcher. Student interview is conducted in this research to get an authentic feedback from the students "customers" about their reflection on the delivery of this TTA-Based TLS and how they interacted and performed in the different activities. These videotaped interviews are analyzed to find that it is appropriate to list in this paper a number of important quotes that hits the depth of students' experience in this TLS design and validation research and then comment and summarize its major trends.

> "It is really an amazing instructional material and teaching approach. Both the layman as well as the educated person can understand deeply the presented concepts."
>
> "When you first exposed to TTA material you will feel overwhelmed by its level of depth, but gradually you will be more and more attached to the harmony and simplicity of its storyline"
>
> "We have to admit that TTA is making a big stride in pulling us from the superficial, fragmented, and meaningless mode of learning to the meaningful, deep, holistic and simple one"
>
> "TTA is distinguished by its ability to simplify concepts and to make the presented knowledge easily understood and deeply engrained in mind"
>
> "Time passed swiftly in TTA-Based TLS workshop because I felt so attached to the sequence of activities that are built based on an entertaining storyline"
>
> "This is the first time in my life that I wish the lecture never ends, because it takes me in a journey in real life to collect and uncover many facts and phenomena that are simple and essential, but I really was not aware of their importance"
>
> "I really like the idea of using flash cards to fragment the concentration definitions then to use them again to build the road map of concentration conversion strategy while interacting with my group members"
>
> "I really like the way this material is sequenced by having a pretest to check initial understanding, a workshop to simplify the material in chunked and structured activities and then a posttest to measure my attainment"
>
> "TTA innovative approach should be implemented not only in universities but in elementary and high schools, because TTA reform should start in earlier stage"

"TTA is an excellent approach that concentrates on deep understanding and not on rote memorization of fragmented and blinded facts"

"The workshop's deep and condensed material needs more than four hours to be perfectly covered"

"I am really amazed by how TLS designer was able to dig deeply in culture to catch the exceptional analogy between Guest-Host relation in our Jordanian Bedouin Culture and solute-solvent relation in solution. This analogy really created an enduring experience"

"Seeds, Roots, Branches and Fruits (SRBF) analogy was really fantastic. It is a very deep and meaningful analogy that is reflected in a smooth storyline of activities"

"The effective use of real life graphics and video clips were strongly catching our attentions to follow the workshop without feeling bored"

"I think, if TTA is implemented to reform education, we will not suffer from being forced to learn in rote and blinded way"

"The real and simple analogies makes TTA superior in creating an enduring understanding"

"Some slides of the workshop instructional material were too crowded with deep concepts, I recommend to spread them on more than one slide"

"The learning atmosphere that is created by the teacher using a variety of teaching tools makes us deeply attracted and attached to the flow of activities presented in the workshop"

These quotes are very insightful in revealing that students were able to get to the depth in analyzing the strengths and weaknesses of TTA in general and solution concentration TLS in specific. They stressed that TTA is characterized by simplicity, storytelling narration, informative graphics, real life video clips, simple and culturally-engrained analogies, enduring understanding, meaningful connections, implementing multi-modeling tools, attractive and engaging learning atmosphere, creating a shift in thinking, uncovering hidden and important basic concepts, growing and constructing concepts, and easy maneuvering between multi cognitive levels.

CONCLUSION

This paper is a result of a huge effort to culminate the TTA conceptualization and customization by producing the first "official" product in the form an optimized and validated TLS. An SRBT TLS design framework is built from scratch to guide the design, planning and validation of this TTA-Based TLS "new born". TTA is a huge overarching framework that accommodates multiple perspectives and multiple modeling tools by maneuvering smoothly between them. Therefore, it is not possible due to paper size limitation to review the literature that concerns everyone of these implemented perspectives and modeling tools. The literature review is only limited to the area of TLS design, planning and validation strategies and frameworks.

This paper culminated the core construct of TTA by presenting and validating a detailed example of a real TTA-Based TLS. The solution concentration TLS opened the door for the wide applications of TTA in reformulating all content area knowledge based on this innovative reform approach. This paper was successful in satisfying the pragmatic value by presenting an experimented and validated TLS and on the same time satisfying the scientific validity by getting a fruitful insights about the teaching-learning process. TTA was successful in unifying educational content areas, knowledge, and in the near future development domains (Education, Industry, Politics, Banking, Management, ….etc.). I cannot claim that this TTA-Based TLS design, delivery and validation is a complete success, but I am confident that this TTA-Based TLS made a big stride in the right direction of offering a model of the successful future instructional material that the world in general and developing countries in specific are urgently in need. It is really amazing when TTA can help the teacher to see the deep understanding in his/her students' eyes

and makes them visualize the road map of the genuine change they need in their way of thinking and performance.

REFERENCES

Aliedeh, M. A. (2015a). Call from the south for Transparent Higher Education (THE) Part 1: Transparent Thinking Approach (**TTA**) Core Conceptual Framework, *Journal of Higher Education Theory and Practice*, 15(5), 103-130.

Aliedeh, M. A. (2015b). Call from the south for transparent higher education (THE) Part 2: Extended Transparent Thinking Approach (**TTA**) Conceptual Framework, *Journal of Higher Education Theory and Practice*, 15(6), 113-140.

Aliedeh, M. A. (2015c). Call from the south for transparent higher education (THE) Part 3: Expanded Transparent Thinking Approach (**TTA**) Conceptual Framework and its Applications in Math, Science, and Engineering Education, *Journal of Higher Education Theory and Practice*, 15(7), 121-142.

Aliedeh, M. A. (2016). Customizing Transparent Thinking Approach (**TTA**) by Building and Implementing TTA Toolboxes: Paving the Road for TTA Operationlization Phase, *Journal of Higher Education Theory and Practice*, 16(5).

Kattmann, U., Duit, R., Gropengieber, H. and Komorek, M. (1995) A model of Educational Reconstruction. Paper presented at The NARST annual meeting, San Francisco, CA.

Leach, J. and Scott, P., (2002). Designing and evaluating science teaching sequences: an approach drawing upon the concept of learning demand and a social constructivist perspective on learning, *Studies in Science Education*, 38, 115-142.

Leach, J. and Scott, P., (2003). Individual and sociocultural views of learning in science education, *Science and Education*, 12, 91-113.

Lijnse, P. (1995). "Developmental Research" as a way to an empirically based "Didactical Structure" of Science. *Science Education*, 79(2), 189–199.

Méheut, M., & Psillos, D. (2004). Teaching-learning sequences: Aims and tools for science education research. *International Journal of Science Education*, 26(5), 515–535. Special Issue.

Viiri, J., & Savinainen, A. (2008). Teaching-learning sequences: A comparison of learning demands analysis and educational reconstruction. *Latin American Journal of Physical Education*, 2(2), 80–86.

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Short Biography of Dr. Mohammad Aliedeh

Mohammad A. Aliedeh is an Assistant Professor in the Department of Chemical Engineering, Mutah University, Karak, Jordan. He completed his Ph.D. at New Mexico State University, Las Cruces, NM, USA, and his undergraduate and Master studies at Jordan University of Science and Technology (JUST), Irbid, Jordan. From 1992 to 1994 he worked as an operation engineer for Jordan Sulphochemical Company, Zerqa, Jordan. His research interests include Multi-phase Flow, Turbulence Modeling, Phosphogypsum Recycling Process, and Engineering Education, Thinking-Based Reform. Recently, He developed and published a new Educational Reform Approach that is called "Transparent Thinking Approach (**TTA**)".

APPENDIX
Solution Concentration TTA-Based Pre Test

Student Name: TTA Student No.:

Solution Concentration TTA-Based TLS Validation Research Pre-Test - Dr. Mohammad Aliedeh

Pre Test

Molarity	Molality	m/m	n/n	ppm
$Molarity = \frac{n_A\,(gmol)}{V_{sol}\,(lit)}$	$Molality = \frac{n_A\,(gmol)}{m_B\,(kg)}$	$\text{Mass Fraction} = \frac{m_A}{m_A + m_B}$	$\text{Mole Fraction} = \frac{n_A}{n_A + n_B}$	$ppm = \frac{m_A}{m_A + m_B} 10^6$

Mass, Volume and Density

Q1: Estimate the volume of a small size Pepsi can in milliliter?

Q2: Estimate the volume of a Mug in milliliter?

Q3: Estimate the volume of the olive oil usually added to "Humus" (Popular Jordanian breakfast dish) plate in milliliter?

Q4: Estimate the volume of water tank that has the dimensions of (1m*1m*2m) in liters?

Q5: Estimate the volume of tank that water distribution truck carry in liters?

Q6: Estimate the mass of 1 liter of water in grams?

Q7: Estimate the mass of 1 liter of olive oil in grams?

Q8: Estimate the mass of 1 liter of Mercury in grams?

Q9: Estimate the mass of 1 liter block of Iron in grams?

Q10: A liquid material filled in a bottle of a volume of 300 ml and a density of 1700 kg/m3, calculate the mass of this quantity in grams?

Q11: Estimate the mass of lab top in kilograms?

Q12: Estimate the mass of a typical medium size Cellular phone in grams?

Moles and Molar Mass

Q13: Calculate the number of moles of 30 grams of NaCl (Table Salt) (Molar Mass =58)?

Q14: Calculate the mass of 10 moles of water (H2O) (Molar Mass =18)?

Q15: Calculate the number of molecules in 10 grams of water (H2O) (Molar Mass =18), Avogadro's number = 6.02×10^{23} ?

Q16: Calculate the mass of one atom of carbon I(Molar Mass =12), Avogadro's number = 6.02×10^{23} ?

Student Name: TTA Student No.:

Concentration Definitions Conversion

Problem (17): Calculate the Molality of 5 Molar solution of Table Salt (NaCl) that has a density of 1.2 g/ml. Molar mass of NaCl is 58 g/mol and 18 g/mol for water

Problem (18): Calculate the Molarity of 5% m/m (mass fraction) of Table Salt (NaCl) that has a density of 1.1 g/ml. The Molar mass of NaCl is 58 g/mol and 18 g/mol for water

Problem (19): Calculate the mass fraction of 20% n/n (mole fraction) of Table Salt (NaCl) that has a density of 1.4 g/ml. The Molar mass of NaCl is 58 g/mol and 18 g/mol for water