The School of Virtual Knocks: Learning from Doing—Without the Pain of Mistakes

by

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The School of Virtual Knocks: Learning from Doing--Without the Pain of Mistakes

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Abstract. The present day educational process, as currently practiced, is no longer necessarily synonymous with learning, and the concept of learning is becoming disassociated with knowledge acquisition. True, learning is not accidental, nor is the absence of learning normally by choice. It is the result, intended or otherwise, of decisions made by government, researchers, educators, students, parents and the wider community. It is underpinned by the quality of teaching, the relevancy of the instruction to the student's world, and the perseverance of the student's desire to learn. It is these choices that are driving the wedge between teaching and learning. The learning outcomes are derived by curriculum developers, educational psychologists, government, and industry. Yet as advances in understanding how students learn have been made, the advances in technology, specifically models and simulation, which are able to underpin complex knowledge domains, have been left behind if not ignored. While a majority of stakeholders in education agree that the current educational environment is missing the mark, it is important to underpin those impressions with a basis of knowledge. This paper reviews education in order to foster the conclusion that education must change and that the enabling methodologies and technologies already exist in the form of models and simulation.

1 INTRODUCTION

Designing an engineering solution for an educational need, such as a particular laboratory exercise or as an adjunct to facilitating a particular lecture, is in itself not a difficult challenge. This is chiefly due to the fact that the *need* is founded in a firm set of educational requirements. On the other hand, mapping an education paradigm and supporting pedagogical foundations to the realm of possible technical solutions is a hefty challenge. This endeavor requires an unbiased inward analysis into how teaching and learning is conducted at present, specifically in grades 6 – 12. This challenge becomes even more difficult given the reality that students are discovering and developing their individual cognitive learning styles, as well as trying to master skills and theories in a multitude of somewhat unrelated subject areas. Yet, this is what this paper proposes and provides both a theoretical and application based solution.

The Advanced Distributed Interactive Simulation Laboratory (ADSIL) at Curtin University of Technology in Perth Western Australia has begun to develop a technology based learning architecture that is grounded in Bloom's Mastery Learning Model, Carroll's Model of School Learning, Gardner's Multiple Intelligences, and the cognitive component of Bloom's taxonomy.

2 MIASMA OR UTOPIA: A MATTER OF PERSPECTIVE

The current educational system has its roots in the industrial revolution [22]. The most important requirement of the time was trained skilled workers. Thus, a student's education was focused on imparting and reinforcing basic skills in reading, writing, and arithmetic, as well as, interpersonal and intrapersonal skills determined as essential in a factory environment. Today, a student is expected obtain enabling skills, acquire knowledge, gain comprehension, demonstrate application, analyze problems, generalize results to other problem domains, and make evaluations based on values and theories. The student is also expected to be creative, adapt to changing circumstances, convert abstract data into relevant information, define and solve problems, and work collaboratively [8],[12].

The education system of today stands in stark contrast to its 19^{th} century roots and is outstripping the ability of the student to learn and teachers to teach as opposed to train. Furthermore the teaching and learning process itself is a complex system of classroom interaction, taxonomies, learning models, intelligences, classroom and home environments, and learning variables, coupled with the emotional, physical, psychological, and philosophical development of the student. Irrespective of the complexity of teaching and learning and ever mindful of the developing learning processes of young students, current researchers into classroom learning agree on two basic points:

1. Students today need to interact directly with key learning domains, not through an interpreter, and

2. Teachers need to evolve from knowledge imparters, or trainers, to knowledge acquisition mentors and tutors.

2.1 A Brief Encounter with The Past

Education, for the most part, evolved to meet the needs of the country, industry, and society for which its student output was intended. It was not until the 1960's that education began to focus on the needs of the students and expectation of parents and community. Thus, to understand the present, a brief look at the education roadmap from the 19th Century forward is important in order to understand the fundamental thinking of the time. Therefore, the following review on education and learning research is essential in order to grasp both the historical evolution of education, and the relevant current theories on how students learn and how best to teach them.

Research into learning since the early 1900's can be divided into four perspectives:

1. The *Differential Perspective* (late 19th to early 20th century) – divide students into skill groups based on their different abilities.
2. The *Behaviorist Perspective* (1930s) – Beyond skills to theories on classroom learning, thus learning required *stimulation* to achieved the desired *response.*
3. The *Cognitive Perspective* (1960s) – Began to treat the mind as a mystery to be understood and not a muscle to be trained or filled.
4. The *Situative Perspective* (1970s) – Recognition that social environments, attitudes, and beliefs impacted the act of learning.

How students were viewed over that timeline is even more enlightening as explained by Husén [18] in his essay on Benjamin Bloom [4] which characterizes this evolutionary process as follows:

> *"When he (Bloom) started his career in educational measurements, the prevailing thesis was: There are good learners and there are bad learners.*
>
> *Then came Carroll's model [9] of school learning: There are faster learners and there are slower learners.*
>
> *Bloom and others began to wonder whether extra time, a student focus on instructional materials, and additional help would bring a far greater proportion of students up to a competence level higher than achieved by the conventional model. This lead to the conclusion: Students become much more similar with regard to learning ability, rate of learning and motivation for further learning if provided with favorable learning conditions."*

Research into empowering the learner has resulted from a number of converging areas such as theories of intelligence, the construction of knowledge, theories of instruction, and the advent of technology. Supporters of individual mastery such as Bloom [4],[5] and Carroll [10], have argued for individual learner focused teaching and learning strategies as opposed to mass education and assessment. In other words stop treating education as an assembly line with the school in the role of the factory, and focus on the desires and needs of the individual learner.

Jean Piaget [25] and Jerome Bruner [7] were among the pioneers that approached the learning process in children by subdividing cognition into distinct modes of reasoning. Other learning theories have also emerged, such as Rogers' Experiential learning [27], Shneiderman's Engagement Theory [28], Vygotsky's Social Development theoretical framework [30], The Social Learning Theory of Bandura [1], and Lave and Wenger's Situated Learning Theory [21], that provide a teaching and learning framework that can be underpinned by technology in order to facilitate individual learning and the development of collaboration skills.

3 DEFINING THE PROBLEM SPACE – THE TECHNICAL FOUNDATION

An engineering problem solving process must be grounded in a firm requirements base in order to derive, design and build a plausible solution. Once a problem is defined, such as the need to modernize and evolve education using technology to its fullest extent, then a solution domain can be formalized. From an engineering perspective, education is a complex system environment only because of humans-in-the-loop (HITL). The reality that how children learn to a certain extent is still an abstract area of research creates additional stochastic and dynamic issues that must be considered in the problem space.

This paper proposes to quantify qualitative learning models and theories into a set of system requirements that will support the design and creation of a holistic teaching and learning process and environment. Furthermore, this paper proposes that the expansion of the application domain of the simulation based training enterprise used in defense [29] and other industries as the technical foundation for the proposed classroom teaching and learning environment.

The contributions of Carroll and Bloom provide an accepted framework within education for the purpose of defining and structuring a curriculum. Hence, this research utilizes the Carroll Model of School Learning, Bloom's Mastery Learning Model and subsequent learning taxonomies of Bloom, and Biggs and Collis as an engineering as the functional and non-functional requirements in support of a technical foundation for the proposed engineering process. Within the field of educational psychology, learning models are used to provide clarity on the answers to the important questions regarding student learning mainly "How do students learn effectively?" [23] and "What is happening in one classroom environment that facilitates better outcomes than in another classroom on the same subject?" [24]. Hence, these questions become the basis of the engineering analysis and proposed solution.

3.1 The Carroll Model of School Learning

John Carroll's *Model of School Learning* [4] states that time is the most important variable to school learning and the efficient use of time by the teacher and the student creates an optimal learning process. Hence, Carroll's model defines five classes of variables that account for variations in student's achievement in school. Three of the variables are expressed as time based differences between students and include: ***Aptitude, Opportunity to learn, and Perseverance.*** The remaining two variables of Carroll's model can be classified as relating to the students ability to achieve and include: ***Quality of instruction*** and ***Ability to understand instruction.*** In essence, Carroll presents the first simple equation to calculate *school learning* from a student's perspective with learning mastery the fundamental goal, and thus provides the basis for quantitative modeling of a learning environment.

$$\boxed{\textbf{School Learning} = f(\textbf{time spent / time needed})}$$

Carroll's model identifies what may be considered as obvious, that there is a relationship between opportunity, ability, motivation, and quality of instruction with respect to student output - learning. Carroll's model provides a framework for assessing the equity of education and the *equality of opportunity* of a student to affect an optimal learning outcome in keeping with their overall ability to learn and comprehend, versus an equality of attainment by increasing the time until all achieve a specified standard [10].

3.2 Benjamin Bloom's Mastery Learning Model

Benjamin Bloom's [5] Mastery Learning Model encompasses the variables of the Carroll Model of School Learning but shifts the focus from equality of opportunity to equality of attainment. Bloom opposed the so called traditional education practice of assuming that the top third of the class will learn the material taught, causing Bloom to note that "this set of expectations, which fixes the academic goals of teachers and students, is the most wasteful and destructive aspect of the present educational system" [6]. Bloom demonstrated through his research that if time is not held constant for learners as it is in most traditional teaching environments, a student's mastery of prerequisite skills rather than aptitude is a better predictor of school learning. In short, Bloom's Mastery Learning model's basic principle is that all students can achieve mastery of a skill or learning outcome given time and quality instruction.

It is important to note that there are other school/classroom models which have been evolved from Carroll and Bloom's work, such as Proctor's Model - 1984 [26], Cruickshank's Model - 1985 [11], Gage and Berliner's Model - 1992 [15], and Huitt's Model – 1995 [17]. Each of these models further define the need for and specify the qualities and characteristics necessary to shift to a student centric style of teaching in learning in keeping with that student's ability to learn, and the quality and presentation style of the instructional material.

3.3 The Bloom Taxonomy for the Cognitive Domain

Following the 1948 Convention of the *American Psychological Association*, Benjamin Bloom took a lead in formulating a classification of "the goals of the educational process" [3]. Bloom headed a group of educational psychologists who developed a classification of levels of intellectual behavior important in learning. The first taxonomy published by Bloom and his co-workers was the *cognitive* domain. The formalization of the cognitive process by which a student acquired, retained, recalled, and then applied knowledge was a key component to Bloom's Mastery Learning Model discussed earlier. Bloom suggests that the proposed hierarchy of learning as leads to a path of *Mastery*, suggesting a student progresses from mastery of a specific subject and associated skills to a mastery of the problem space - a shift from subject relevancy to problem abstraction. In other words, the student first learns all the associated knowledge for a particular domain and then shifts to mastery of all similar problem domains.

3.4 The Structure of the Observed Learning Outcome (SOLO) Taxonomy

Whereas Bloom's Taxonomy classifies cognitive learning objectives within a specified domain, the **S**tructure of the **O**bserved **L**earning **O**utcome (SOLO) taxonomy developed by Biggs and Collis [2] sets out to provide a systematic way of describing how a learner's performance grows in complexity when mastering many tasks undertaken in school. A general sequence in the growth of the structural complexity of many concepts and skills is postulated, and that sequence may be used to guide the formulation of specific targets or the assessment of specific outcomes.

4 THE CLASSROOM REALITY – TODAY AND WHAT'S POSSIBLE TOMORROW

It is generally accepted that the first three levels of Bloom's taxonomy – *knowledge, comprehension, and application* – deal with the solution space of a particular learning domain. Hence students are taught skills and supporting theories that supposedly enable them to make inference and draw conclusions about the larger, more nebulous learning space. For example, physics in most textbooks has forty-four somewhat distinct subject areas. Students are expected to grasp the foundations of physics for the purpose of designing and experimenting about each of those subject areas in order to reason about our world, solar system, and universe [31].

Unfortunately, it is the next three levels of Bloom's taxonomy – *analysis, synthesis*, and *evaluation* – that help the student develop the enabling skills to conduct those experiments and reason about their meaning and draw practical inference for the related physical domain. More unfortunate is the inability of students in a practical, safe, and interactive environment to explore those fundamental cause and effect relationships necessary to grasp the larger picture. The targeting of technology at these issues can provide the necessary tools for students to explore and conduct experiments on complex relationships, and create learning environments, such as the virtual lab to facilitate learning by doing.

4.1 The Cognitive Learning Loop – Mapping Technology to the Classroom

As presented, there is a desire to shift from the stand-and-deliver classroom model towards a more pragmatic student centered approach. This shift has been hindered though, due to the lack of a holistic learning strategy that couples the use of technology with relevant problem areas facing current teaching and learning practices. What is important though, is that technology in the form of integrated visualization supported by animation and modeling and simulation, and enabled by a suite of integrated teaching and learning tools, architectures, and methodologies can bridge that gap. Mapping flexible technology structures and approaches to descriptive learning taxonomies such as, Bloom's Taxonomy and *The Structure of the Observed Learning Outcome (SOLO)* by Biggs and Collis provides a framework for organizing and presenting instructional material.

A specific learning objective or skill is mapped against the desired level of presentation to index, guide, and enhance learning. The next step in the cognitive learning loop is to map the intended instruction to the student's preferred intelligence, or cognitive learning style. Actual presentation styles are determined based on the student's pre-determined mental model or mode of learning. Students are then presented the objective or skill to be learned based on the student's *learning strategy* in a contextual setting once again pre-determined. Finally, a student is assessed based on the desired outcome and the student's actual ability. If the student has mastered the particular objective, the process can begin over by either developing a deeper understanding or mapping the new knowledge to a body of knowledge already mastered. Deficiencies on the other hand result in a revision strategy to help the student recognize problems in their understanding so that they can attain the required outcome.

According to most cognitive learning theories, when a student is introduced to an instructional component, the student will map what is to be learned to a mental model and learning strategy based on the type of innate intelligence the student brings to the learning process. By modifying Bloom's taxonomy to serve as a guided cognitive development strategy, instruction is automatically organized beginning with basic structures to the more complex as recommended by theories of instruction presented earlier. Accounting for different modes of learning, multiple innate intelligences [16] and Bruner's learner focused instruction allows then for students to formulate mental models and learning strategies determined by their mode of learning and predisposition to a particular intelligence. Incorporating the concepts of SOLO to determine *how* a student knows the instructional material, provides a benchmark for designing appropriate mastery revision steps which can be applied if required, else the student can be moved to the next stage of the guided cognitive development level.

5 CREATING A CLASS ACT – MODELS AND SIMULATION

The essence of computing is data processing or more fundamentally to gather, manipulate, store and retrieve data. Therefore, a technology solution to support education is based on using computers to process data in a timely and efficient manner in order to support the teaching and learning relationship of the presentation and knowledge acquisition. By mapping a data processing strategy to a physical computer network topography, software architecture, and a specific teaching and learning model and taxonomy, the system and functional requirements for a set of teaching and learning technology based tools can be defined and integrated with other T&L strategies. Hence, if the desire is to create a holistic learning environment that can accommodate the learner and facilitate learning, alleviate the teaching burden, and expand as the learning domains expand, then model and simulation is the essential key to unlocking the future potential of the classroom learning process.

The current supporting technologies, architectures, and standards can support an entire range of classroom activities. The *High Level Architecture* (HLA) [29] [19] [20], currently utilized by many of the NATO defense forces to conduct training, can also support education. The HLA serves as an information broker at the individual level to a fully distributed collaborative learning process.

5.1 The Role of Models

Models provide the ability to visualize actions and reactions in the physical world while also allowing the student to learn about the underlying mathematical and qualitative principles which govern those actions and reactions. Classroom models can be simplistic visualizations such as an animation of Newton's Laws of Motion, with no connectivity to the underlying principles that are being viewed. On the other hand, models can be highly accurate representations of the underlying mathematical and physical interactions that provide inputs to the model, thus allowing for manipulation of the state change variables as the modeled objects evolve over time. While the concept of a model is fairly clear, the process for applying it to a holistic learning process is not. Without a classroom learning model (environment) and taxonomy for learning, the subject specific models become just another teaching and learning resource without a mechanism for determining what the goal of the model is in relation to the overall teaching and learning strategy.

Bloom's taxonomy allows for mapping a model's fidelity and resolution requirements to a specific level of the knowledge acquisition and cognitive development process. If the focus is to impart basic information, than a simplistic animation may suffice, but if the goal is to support synthesis and evaluation of alternative solutions, then domain specific and age appropriate interactive models are required. Interactive models facilitate exploring solutions by allowing students to change input values and observe the impact on the state changes and output variables. More importantly, though, a model's validity comes from its ability to provide instruction through observation and interaction.

5.2 The Role of Simulation

Simulation is the joining of models into a more complex system to be observed and interacted with. The simulation environment can include models, real equipment, and students [13]. Simulation provides students a real-time portal to knowledge in a visual domain. As students experiment with the causality of why things work, they learn from observation the effect on the expected outcomes. Simulation also provides a mechanism for rolling up fundamental theories into more complex environments. Hence as models are intended to represent specific components of an application space, simulation joins the component modes into a holistic interactive dynamic environment.

Once again, the previous learning models and taxonomies serve as the functional and technical requirements for creating the simulated environment as well as defining the allowed interactions between the models

5.3 The School of Virtual Hard Knocks – A Plausible Teaching and Learning Architecture

Any teaching and learning (T&L) architecture has three facets: system, functional, and technical. Defining, designing, supporting and maintaining a T&L architecture is not an easy matter, and wrong decisions have risks associated with cost, student outcomes, and quality of instruction. Technology itself is ever advancing, making decisions on what equipment to select and how to acquire them a difficult challenge. Yet armed with this knowledge, fundamental decisions between alternatives can reduce this risk tremendously.

The High Level Architecture (HLA) provides a communication architecture that is supported by vendors around the world. Currently, the focus of existing HLA compliant tools and models is on defense skills and training, but many of the same models can be easily converted to classroom T&L models in support of a exploration based learning process. The HLA also provides a framework for mapping technology to a specific curriculum given a learning model and taxonomy. This framework is designed as a six step problem solving and engineering design and implementation strategy. By evolving it to an educational paradigm with a supporting pedagogy, the process can be expanded to include other T&L supporting resource models for student mentoring, monitoring, and assessment. As the education community becomes more technology savvy and friendly, the commercial reality is that vendors will meet their needs.

6 VIRTUAL MISTAKES

Typically mistakes made in life come with a certain degree of discomfort. Mistakes made in the current classroom learning process results in poor performance and bad marks. Mistakes of cognition have even deeper consequences if not caught and corrected. The ability of models and interacting simulations provide a virtual learning space that deepens a student's understanding of seemingly disparate subjects and desired learning outcomes. Mistakes can be made, analyzed, and corrected either overtly or covertly depending on the current instructional focus.

The concept of *mistake space reasoning* provides students with a mechanism to evaluate wrong decisions and their impact on the overall problem. By analyzing what went wrong, a student may not know intuitively what to do, but the student will know what not to do and why. The classroom can thus be transformed from a risk free antiseptic environment to a true exploration process of which mistakes form a vital part of the learning process. [14]

7 SUMMARY

Engineering can use current technology to propose a solution for mapping technology to a particular learning objective. To underpin the engineering process requires a credible and achievable learning model, a valid learning classification or taxonomy, and a process for measuring potential and outcomes. The concept of exploring knowledge through guided instruction and mentoring in a technology enhanced learning process and environment requires a shift in present classroom practices. The reality is, for more information to be added to the curriculums in secondary and arguably tertiary education requires a mechanism for aggregating the separate bodies of knowledge into a more cohesive holistic learning process and environment. Models and simulation can support the full spectrum of learning as it is supporting the full range of training today.

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The School of Virtual Knocks

Learning by Doing – Without the Pain of Mistakes

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In the Beginning…

- Modelling
  - Types of models
    - Scale, Iconic, symbolic
  - Characteristics of model
    - Representation of action and interaction
    - Representation and use of time
    - Interoperability
- Simulation
  - Interaction of and with models over *time* for a specific reason

Realm of Possibility

- Disparate set of tools focused at supplementing the classroom model
  - I.E., Tutoring systems, Animations, text
  - Typically incorporated for issues other than learning – time, resource, and student management

To

- Holistic learning environments
  - The virtual and real mistake space

What if You Were Asked to...

- Design a curriculum from scratch and
- Design a school from scratch, with
- No past biases, no sacred cows, and no guidance?

- ***The response was***
  - An Exploration-Based Curriculum , and
  - *The Australian Science Academy (ASA)*

Foundations

- Engineering to the rescue
  - Problem space – "What problem?"
  - What is "technology"
- Solution Space
  - Taxonomies
  - Learning Models

The Quest for Understanding Learning

—The Learning Puzzle—

Learning Domains

- Aviation
- Computers
- Concepts
- Decision Making
- Engineering
- Language
- Management
- Mathematics
- Medicine
- Military
- Perception
- Problem Solving
- Procedures
- Reading
- Reasoning
- Sales
- Sensory-Motor
- Troubleshooting

Historical Perspectives

- *Differential*
- *Behaviourists*
- *Cognitive*
- *Situative*

Taxonomies

- Bloom's
- SOLO

Historical Foundations

- Role of Education throughout History – Survival to Enlightenment
- Critical Discoveries that shaped learning
- The major points of reform

Learning Models

- Bloom's Mastery Learning Model
- Carroll Model
- Holographic Model

Learning Concepts

- Anxiety
- Arousal
- Attention
- Attitudes
- Cognitive/Learning Styles
- Creativity
- Feedback/ Reinforcement
- Imagery
- Learning Strategies
- Mastery
- Memory
- Mental Models
- Metacognition
- Motivation
- Productions
- Schema
- Sequencing of Instruction
- Taxonomies

Learning Theories

- ACT*
- Adult Learning Theory
- Algo-Heuristic Theory
- Andragogy
- Anchored Instruction
- Aptitude-Treatment Interaction
- Cognitive Dissonance Theory
- Cognitive Flexibility Theory
- Cognitive Load Theory
- Component Display Theory
- Conditions of Learning
- Connectionism
- Constructivist Theory
- Contiguity Theory
- Conversation Theory
- Criterion Referenced Instruction
- Double Loop Learning
- Drive Reduction Theory
- Dual Coding Theory
- Elaboration Theory
- Experiential Learning
- Functional Context Theory
- Genetic Epistemology
- Gestalt Theory
- GOMS (Goals-Operators-Methods-Selection
- General Problem Solver (GPS)
- Information Pickup Theory
- Information Processing Theory
- Lateral Thinking
- Levels of Processing
- Mathematical Learning Theory
- Mathematical Problem Solving
- Minimalism
- Model Centered Instruction and Design Layering
- Modes of Learning
- Multiple Intelligences
- Operant Conditioning
- Originality
- Phenomenonography
- Repair Theory
- Script Theory
- Sign Theory
- Situated Learning
- Soar
- Social Development
- Social Learning Theory
- Stimulus Sampling Theory
- Structural Learning Theory
- Structure of Intellect
- Subsumption Theory
- Symbol Systems
- Triarchic Theory

A Matter of Perspective

- The *Differential Perspective* (late 19th to early 20th century) – divide students into skill groups based on their different abilities.
- The *Behaviorist Perspective* (1930s) – Beyond skills to theories on classroom learning, thus learning required *stimulation* to achieved the desired *response.*
- The *Cognitive Perspective* (1960s) – Began to treat the mind as a mystery to be understood and not a muscle to be trained or filled.
- The *Situative Perspective* (1970s) – Recognition that social environments, attitudes, and beliefs impacted the act of learning.

How We View Students
- Theoretically Speaking -

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- *When Bloom started his career in educational measurements, the prevailing thesis was:*
  - *There are good learners and there are bad learners.*
- *Then came Carroll's model of school learning:*
  - *There are faster learners and there are slower learners.*
- *Bloom and others began to wonder whether extra time, a student focus on instructional materials, and additional help would bring a far greater proportion of students up to a competence level higher than achieved by the conventional model. This lead to the conclusion:*
  - *Students become much more similar with regard to learning ability, rate of learning and motivation for further learning if provided with favorable learning conditions (inspiration).*
- What's Changed???
  - View of the mind
  - Worth of a single student

Exploration Based Education

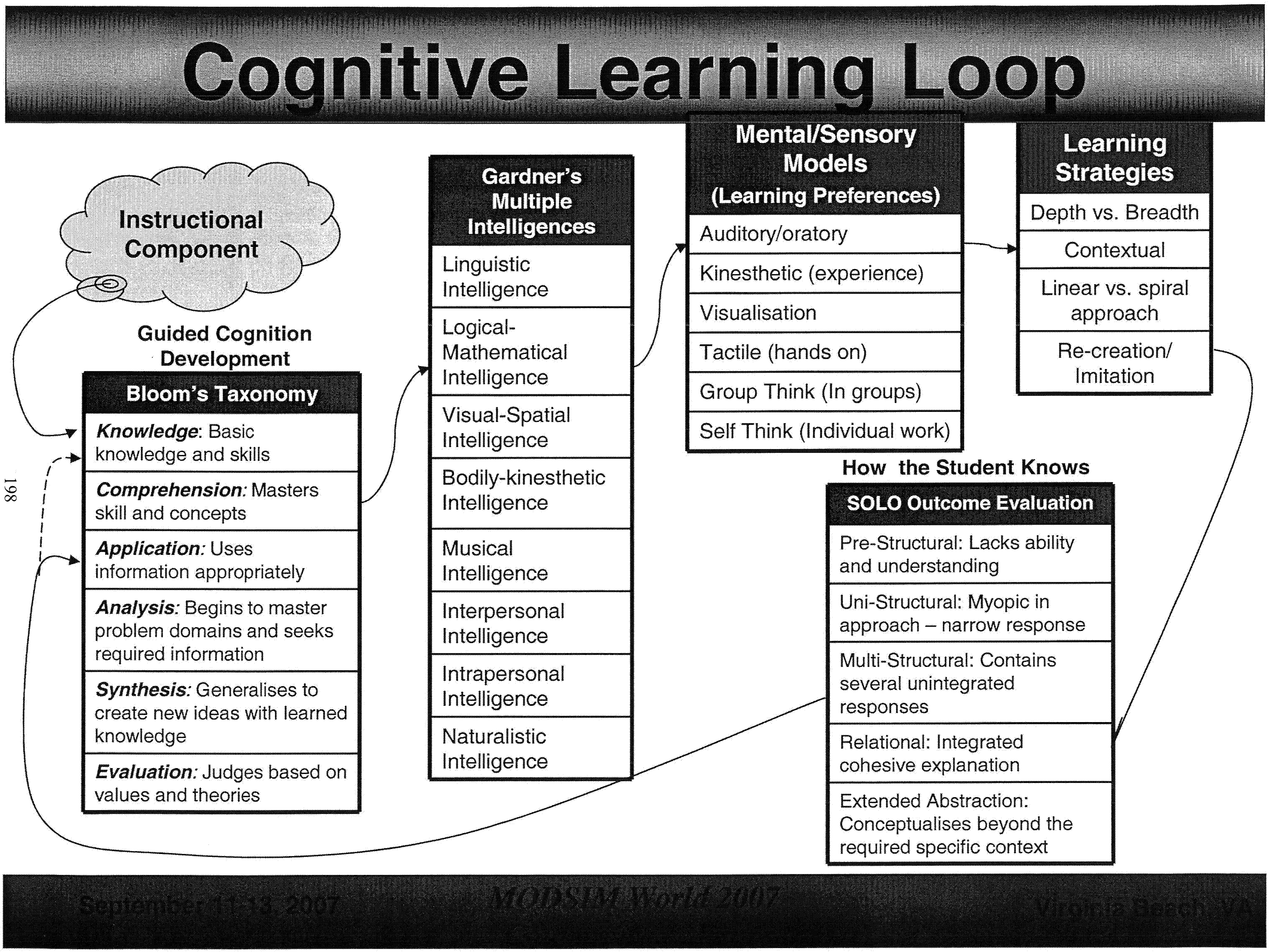
- The concept of discovery in an application paradigm given domain problems to research, analyse and solve
- Horizontal integration- from reduction to aggregation
- Application domain designed
- Uses technology to enhance activities, provide information, allow for what if analysis – foster and mentor learning

Engineering Framework

- Pedagogical Foundations
  - Bloom's Taxonomy
    - Cognitive, Psychomotor, Emotional
  - *The Structure of the Observed Learning Outcome (*SOLO) Taxonomy
  - Carroll's Model for School Learning
    - The role of time
  - Gardiner's Multiple Intelligences

Engineering Requirements

- Technical
  - Standards, practices, policies, and procedures
- System
  - Technology backbone
- Functional
  - What the environment will provide, expect, and react to


Cognitive Learning Loop
Instructional Component
Guided Cognition Development
Bloom's Taxonomy
Knowledge: Basic knowledge and skills
Comprehension: Masters skill and concepts
Application: Uses information appropriately
Analysis: Begins to master problem domains and seeks required information
Synthesis: Generalises to create new ideas with learned knowledge
Evaluation: Judges based on values and theories
Gardner's Multiple Intelligences
Linguistic Intelligence
Logical-Mathematical Intelligence
Visual-Spatial Intelligence
Bodily-kinesthetic Intelligence
Musical Intelligence
Interpersonal Intelligence
Intrapersonal Intelligence
Naturalistic Intelligence
Mental/Sensory Models (Learning Preferences)
Auditory/oratory
Kinesthetic (experience)
Visualisation
Tactile (hands on)
Group Think (In groups)
Self Think (Individual work)
Learning Strategies
Depth vs. Breadth
Contextual
Linear vs. spiral approach
Re-creation/ Imitation
How the Student Knows
SOLO Outcome Evaluation
Pre-Structural: Lacks ability and understanding
Uni-Structural: Myopic in approach – narrow response
Multi-Structural: Contains several unintegrated responses
Relational: Integrated cohesive explanation
Extended Abstraction: Conceptualises beyond the required specific context
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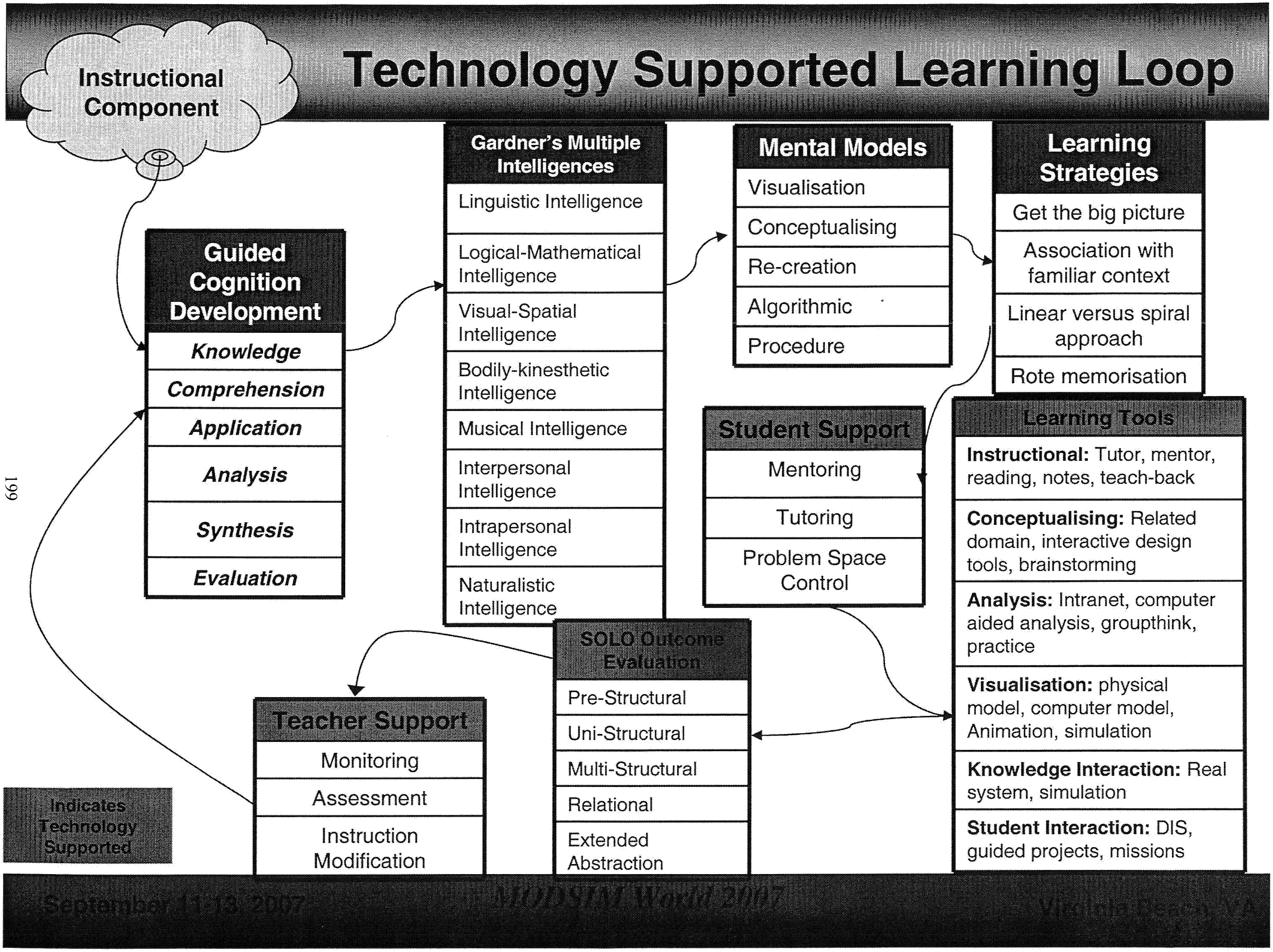
Technology Supported Learning Loop
Instructional Component
Guided Cognition Development
Knowledge
Comprehension
Application
Analysis
Synthesis
Evaluation
Gardner's Multiple Intelligences
Linguistic Intelligence
Logical-Mathematical Intelligence
Visual-Spatial Intelligence
Bodily-kinesthetic Intelligence
Musical Intelligence
Interpersonal Intelligence
Intrapersonal Intelligence
Naturalistic Intelligence
Mental Models
Visualisation
Conceptualising
Re-creation
Algorithmic
Procedure
Learning Strategies
Get the big picture
Association with familiar context
Linear versus spiral approach
Rote memorisation
Student Support
Mentoring
Tutoring
Problem Space Control
Learning Tools
Instructional: Tutor, mentor, reading, notes, teach-back
Conceptualising: Related domain, interactive design tools, brainstorming
Analysis: Intranet, computer aided analysis, groupthink, practice
Visualisation: physical model, computer model, Animation, simulation
Knowledge Interaction: Real system, simulation
Student Interaction: DIS, guided projects, missions
SOLO Outcome Evaluation
Pre-Structural
Uni-Structural
Multi-Structural
Relational
Extended Abstraction
Teacher Support
Monitoring
Assessment
Instruction Modification
Indicates Technology Supported
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The Australian Science Academy

- Years 7 - 13
- Three primary learning domains (Structures)
  - ***Space and Beyond*** – The Universe
  - **Spaceship Earth** – Our planet
  - **The Journeyers** – Our humanity
- Three physical levels of interaction
  - Instructional – Learning Centers
  - Experimental – Exploration Centers
  - Real-world – Activity Centers

The Vision

- A prototype campus for learning, evaluation, research and development, and creation of teaching resources
- Constantly evolving
  - Technology
  - Teaching and Learning (T&L) processes and practices
- Use of resources for different learning processes
  - Camps, training, diploma
- Educational Global Village
  - Seamless transition from grade to grade and system to system