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Section 1 - Thesis: Knowledge as Meaning through Embodiment and the implications for the machine

I. Abstract

- 1] Technology is not inherently good or bad, technology is what we make of it.
- 2] Historically, within the context of education, the role of the machine has been seen as a solution to predefined problems, problems that span a social, political and historical landscape.
- 3] Enmeshed within this landscape have been the scientific pedagogy of judging behavior and establishing purpose, psychological learning theories and educational ideologies that have lent themselves best to societal needs, technobureaucratic ideologies of capitalism and technics of positivism and psychology that eventually established a symbolic, rationalized consciousness about the purpose of education.
- 4] Consequently, the field of "Instructional" Design has emerged within the practice of the machine as a socially and historically constructed object, a construction referring to a world view grounded in the efficient production, dissemination and control of knowledge and embodying the interests of those who will benefit from its existence.
- 5] Rooted in an objectivist epistemology that underlies both behaviorism and the information-processing-based cognitive psychology, the repercussions of such a pedagogical appropriation of technology have been those for how we understand not only human learning but the nature of mind itself.
- 6] From the teaching machines of Sidney Pressey and B.F. Skinner to the Computer Aided Instruction (CAI), Instructivist Design and mass information dispensing paradigms of today's modern computer, one can clearly evidence how the language of the machine becomes the language of human thought and reason.
- 7] What is unromantic about the appropriation of technology within unchallenged paradigms of educational practice is how it is assimilated into a discourse that seems universal and beyond human reproach with the machine being given a presence equitable with quality, progress, science, nationalism and the future. Consequently, the view of technology - what it does, can do and how it affects the individual and society at large becomes representative of this discourse.
- 8] Pedagogical practice governed by societal needs, curriculum objectives and philosophical ideologies at large, has long favored a view of technology that has adhered to Instructivist Design principles that regard knowledge as something that is objective and independent of the subjective mind and one that can be efficiently communicated through the formulation of observable objectives.
- 9] Such Instructivist Design principles lend a view of the mind as an efficient information processing system and learning as a passive act of receiving and reproducing the transmitted information. What is more important is the fact that it gives rise to what I call as the 'vicious cycle of metaphorical technological practice' in which science is practiced by following the logic of a metaphor, such as "the computer is like a human subject" subsequently followed by research that implicitly dissolves the metaphor and makes it real.
- 10] Within this cycle, it is then difficult to see the process of learning as anything other than the passive act of acquiring information and the role of the machine as anything other than facilitating the imposition of facts and concepts from the transmitter to the recipient.
- 11] It is not that the Instructivist Design approach to education has been unchallenged. Constructivism as a learning theory originating out of the works of Piaget, Bruner and Vygotsky has long been advocating the fact that humans construct their own knowledge and meaning of the world and that the educational process and the

appropriation of technology within it should be seen as one that scaffolds this process of active learning as opposed to one that objectively imposes facts and knowledge on the learner.

12] Although Constructivist Design principles are being increasingly considered by educators within classroom practice, practical realizations of these other than Robert Davis's PLATO system based on Bruner's Discovery Learning approach, Suchmann's Inquiry Training Model or Seymour Papert's LOGO programming language based on the ideas of Piaget have been relatively few and far between. The more recent attempts by Duffy, Cunningham and Jonassen have taken the form of Constructivist Learning Environments (CLEs) such as Webquest which are trying to apply constructivist principles within the domain of the networked computer.

13] What is however of critical importance to note is that Constructivist Design as a practice hasn't been applied outside the adopted paradigms of the modern computer such as the desktop model and the subjection of experience to its artificial screen reality, paradigms that impose severe limitations to constructivist applications. Moreover, such a constructivist practice has approached the process of active learning only in terms of programmed thinking, problem solving and logico-mathematical thought processes initiated by the learner, an example of which is LOGO where the learner thinks in terms of programmed sequences that control a turtle that draws graphics on the screen.

14] The point I wish to bring out is the fact that Constructivist Design operating within the model of the desktop computer has not been able to adequately translate constructivist principles into practice, restricting the learner's activity to programmed thinking and vision as the dominant perceptual mechanism of the learning process.

15] Consequently, there hasn't been an approach within Instructional Design that is theoretically grounded in the fact that learning is a process of one's embodied interaction with the environment and that knowledge cannot be separated from the act of being. The role that senses play in a child's intellectual development has not been adequately considered, the importance of which has long been advocated in early Montessori schools and by prominent thinkers such as Jean Rousseau.

16] Moreover, the mode of thinking in the active learning process that I consider of greater importance is one of higher order thinking such as subjunctive thought that is fundamental to a child's creativity and one that enables it to acquire the larger meaning of things and allows for different interpretations of what is ordinarily conceptualized and perceived, something that the psychologist Edward De Bono calls as lateral thinking as opposed to programmed thinking. I thereby see a necessity to approach Instructional Design in these terms.

17] In order to approach this problem adequately, I ground my design within the theoretical literature of constructivism and embodied cognition, two interdisciplinary fields of research that I believe have more in common than when considered in isolation. Moreover these complement each other in the sense that while constructivism does not elaborate on the 'active' component of knowledge construction, embodied cognition can be seen as completing the picture with this activity being grounded in the learner's embodied and sensorimotor experiences.

18] From such a theoretically reflexive approach that I partly attribute to Micheal Hannafin's conception of 'Grounded Constructional Design', I derive a set of definitions of the learning process which then are subsequently translated in terms of design implications for the appropriation of technology within pedagogical practice.

19] These design implications are then realized in terms of a project called M-CLE which is an Embodied Constructivist Learning Environment, the characteristics of which are compared with the LOGO programming language such as recognition of the fact that the human brain is more like a pattern recognizing system rather than a computer.

20] Most importantly however, what I wish to argue over the course of this thesis is the fact that given the construction of the machine as a socially and historically constructed object and the pedagogical technological practices that have evolved as a result of this construction, it is always a challenging task to break through established paradigms. Nevertheless, I believe that **micro-change through practice is possible** as evidenced by the LOGO programming language, one that can have a significant impact on how we begin to think of what is possible with technology and our subsequent understanding of the process of learning and the nature of mind. This view of seeing a more positive appropriation of technology is also something that Papert talks about when he introduces the term 'technocentrism'.

However, within this optimism is an increasing belief that the **model of the desktop computer is not a correct one to approach such a change** given the constructivist design applications that have operated within this model, and this is where I argue strongly against Papert's ideologies of seeing the computer and its simulated environment as one that will allow for such a change. Moreover, I place a significant amount of importance on lateral thinking that allows for a child's higher order thinking to develop and his understanding of the larger meaning of things, as opposed to programmed thinking within this change. One of the threads that I keep on coming back to is the fact that the machine has to lend itself to the embodied nature of our learning process and that we need to look out of this model that subjects the human experience to its own artificial reality. The machine then, as it exists in its present form is a bridge between our past and the future, one that is iconic of the past practices within instructional design, yet provides us with hope to look towards a more positive adoption of emerging technologies such as embedded, ubiquitous computing and advances in robotics and hybrid technologies.

Given the forces that control its existence, technology will continue to find its way into pedagogical practice. What is important however is to raise an awareness of the implications of the theoretical underpinnings of instructional design that continue to guide its practice. For this to happen, micro-change that realizes alternative approaches to the pedagogical appropriation of technology has to occur and this change has to take place in a larger number of elementary school settings. Our adoption of technology in these settings is critical to how we allow our children to evolve with our machines and ultimately to what kind of thinkers we produce in our society, a call that was long made by Piaget. I thereby take the model of the child within a K-8 age group as my test subject within M-CLE.

Keywords - Learning, Knowledge, Meaning, Pedagogy, Constructivism, Embodied Cognition, Senses, Technology, Child, Play, Creativity, Instructivist, Constructivist, Design

II. Chapters

A. Historical, socio-cultural contextualization of the role of technology within pedagogical practice

i. *The machine as a socially and historically constructed object*

Legend has it that in olden times, probably during the Middle Ages, the good city of Nuremberg in Germany had in its possession a big funnel called as the Nurnberger Trichter that funneled instant knowledge into the dense heads of its citizens. The city was much envied throughout Europe for this device, though legend does not disclose whether the honorable citizenry of Nurnberg was particularly known for its wisdom. If it was, this wisdom has been lost to history, just as the funnel seems to have been lost. The only memory that remains is the German verb *eintrichtern* or to pour in through a funnel, the connotation being "forcing knowledge".

The 20th and 21st century models of the Trichter have been manifested in the form of technological artifacts such as radio, motion picture, television, teaching machines, programmed instruction, the computer, internet and interactively networked multimedia technologies for distance education. ***From the advent of timepieces to the demands of today's information age, the machine has become part of the solution to predefined problems, problems that span a social, political and historical landscape. No matter what form it takes, it would almost sound too naive to see the machine as a neutral, nonhistorical and nonsocial object. The machine is a socially and historically constructed object referring to a world view grounded in the efficient production, dissemination and control of knowledge. The machine as a cultural form, as a symbol, embodies the interests of those behind it, serving those who will benefit from its existence.*** Within the context of education, the machine has been given a presence equitable with quality, progress, science, nationalism and the future. Enmeshed within this viewpoint have been philosophical ideologies, historical concerns, societal needs, curriculum objectives, the authority of the state and business and the dynamics of power relations over the control and implementation of media within educational environments.

The history of technology in education has always included a discourse linking its use in classrooms to the perceived needs and interests of the socio-political and economic world. Historically, the practice of instructional technology has emerged within a context of scientific pedagogy of judging behavior and establishing purpose, psychological learning theories and educational ideologies that have lent themselves best to societal needs, technobureaucratic ideologies of capitalism and technics of positivism and psychology that eventually established the consciousness of a scientific management of instruction. One can clearly evidence this within the discourse of education in the United States that is grounded in behaviorist and positivist ideologies. From a behaviorist perspective, outcomes and products are what learning and effective instruction are founded upon.

ii. *The resonating impact of Teaching Machines and the Programmed Instruction Movement*

Behaviorism as a psychological theory of learning which maintains that no philosophical differences exist between publicly observable processes (such as actions) and privately observable processes (such as thinking and feeling) positioned itself well within the social efficiency movement of the early 20th century which was the site of conflicts over the control of curriculum. Schools, like societies, were viewed as nonproductive, lacking direction and purpose, wasteful of time and needing to be fixed. The empirical work of Sidney Pressey and B.F Skinner based on the efficient conditioning of behavior as a response to environmental stimuli provided the technology necessary for the kind of controlled assessment and prediction of student behavior that a curriculum based upon a social efficiency doctrine required. ***The significance of this doctrine that still resonates in today's postmodern world is the view of intelligence in terms of points and scales. That intelligence tests became the benchmark for regulating society, increasingly called for the mechanistic control of the right and wrong kinds of human behavior. What was however of greater significance was the fact that increasing similarities began to be drawn between the operation of the mind and that of the machine.***

Advancing this viewpoint was the emergence of the ***Teaching Machine, Programmed Instruction*** and ***Systems Approach*** to identifying and solving educational needs, all of which have been causal to the ***Computer Aided***

Instruction (CAI), Instructivist Design, Integrated Learning Systems (ILS) and mass information dissipation paradigms of today's educational environments under the banner of individualized instruction, ***paradigms that have been rooted in an objectivist-cognitivist view of the world, ones that approach the construction of technology in terms of prioritizing information, facts and concepts over knowledge construction.*** The roots of today's educational appropriation of computer technology can be attributed to the instructional design movement pioneered by the prominent practitioners of the behaviorists era, a movement based on the singular mode of inquiry, namely, the empirical-analytic mode that sought to apply an efficient scientific technological model to the perceived needs of education within a socio-cultural milieu dominated by such major historical events such as World War II from which efficient models of mass training were appropriated or the launch of the Sputnik which was perceived by the US as an educational crisis that demanded a greater proportion of analytical skills to be introduced as part of the curriculum. Within these societal needs, Edward Thorndike's science of instruction with the philosophy of an objective-driven curriculum, Pressey and Skinner's teaching machines that enforced drill and practice were seen as solutions to the immediate problems of the state. In *"Teaching Machines: From the experimental study of learning come devices which arrange optimal conditions for self-instruction"*, Skinner writes that ***"There are more people in the world than ever before, and a far greater part of them want an education. The demand cannot be met simply by building more schools and training more teachers. Education must become more efficient"***.

The significance of Skinner's comment is firmly rooted in our cultural metaphors of the efficient machine and an exact and neutral science. Our inheritance from the enlightenment has provided us with images of the machine effectively controlling nature and men and a science based on positivism that propagates a reconstructed logic, truth and the ability to predict. ***The teaching machine and its present day incarnation in the form of the computer is an embodiment of the conflicting and changing socio-historical theories and movements, political and economic conflicts between management and labor, and a science of education that has constructed a symbolic, rationalized consciousness about the purpose of education and the teaching machine. The resonating impact of the teaching machine in the form of today's hi-tech educational tools continues to be felt amidst political agendas such as the No Child Left Behind Act of 2001 which enacts the theories of standards-based education reform based on the belief that establishing measurable goals, imparting specific skill sets to students and increasing the standards of accountability of schools can improve individual outcomes in education.***

iii. Understanding the impact

What is however of greater importance to understand is the fact that ***within the practice of the machine as a socially and historically constructed object, the focus has been largely on the appropriation of the machine within unchallenged paradigms of educational practice and psychological learning theories that have best served the multiple interests of the state and society and those of achievement and progress, ones that are assimilated into a discourse that seems universal and beyond human reproach. Consequently, the view of technology - what it does, can do and how it affects the individual and society at large becomes representative of this discourse.*** How the modern teaching machine (the computer and its instructional program) has and will influence society and the way education, teaching and learning are thought of, is critically important to those who teach and learn and those who will teach and learn.

B. Repercussions of the historical and socio-cultural construction of the machine

i. The Vicious Cycle of Metaphorical Technological Practice

The use of information technology ties older millennial views about schooling with New World professional ideologies that can be progressively obtained through the science of the individual. What is significant about current technologies is the union of information technologies and cognitive psychology. Student and teacher competence become defined through the discourses of technologies originally designed to "augment" classroom practices. ***The language of reason and rationality borrowed from science and the machine language of the computer are made into a language of learning and thinking.***

When science is practiced by following the logic of a metaphor, such as "the computer is like a human subject", problems can be productively solved within the logical limits of the metaphor. In the context of education, **research implicitly dissolves the metaphor and makes it real**. Students are problem solvers and information processors. The mind exists to process information: A student's capabilities to solve problems are related directly to how well he or she communicates which in turn is based on the limited amount of information he or she receives. In turn, the reception of information is conceived as constrained by limited sensory capabilities, initiative, the ability to process the information, and the quality of the information. **The language of school learning and reform is made into a discourse binding the psychology of the individual with the functioning of the computer. The language of the machine becomes the language of human thought and reason.** The algorithm refers to a bounded rationality; to a cybernetic interface to enhance and extend human thinking and problem-solving capabilities including an integrated domain of hunches, cut and try, and intangibles (a "feel for the game") combined with powerful mediated knowledges, sophisticated methods, and high-powered information technologies.

The incorporation of this metaphoric language into the applied practices of psychology results in the misrecognition of the computation metaphor as a research tool. **Historically, the Turing Machine provides an example in psychology.** After the popular reception of the Universal Turing Machine (UTM), a euphoria descended that suggested that all things can be represented in computer models. Through continued research, apparent correspondences increase between cognition and computation and the social tensions and boundaries between them, including the metaphor, begin to wane.

A result of these social practices is that the metaphoric language used to explain relations between computation and cognition is reversed - "the computer is like the human subject" becomes "the human subject is like the computer." The social management of curriculum and learning, furthered by recent practices of information technology, sustain both the reversal and collapse of the metaphoric description of cognitive activity into literal meaning in educational research. **Although there are efforts to develop oppositional discourses about technology and thought, the union of cognitive psychology and information processes are authoritatively positioned.** This occurs through sponsorship from the state, businesses and foundations. **It is also given legitimacy through the historical patterns embedded in contemporary educational practices.** The social transformations, of which cognitive science is a part, entail new systems of social regulation of the individual. In the words of Foucault, a technology of the "self" is implied in the alchemy of this science that makes the human into a machine, although a different machine than those of the first industrial revolution.

ii. Experience as Simulation through the Creation of an Alternative Reality

The "universe" which we can create on a computer screen is a small, highly edited simulation of reality. Moreover, it is a universe created by a small, highly edited simulation of ourselves. Only one narrow band of our experience is represented in the computer: logical reason. Sensual contact, intuition, inarticulated commonsense judgments, aesthetic taste have been largely, if not wholly, left out. We do not bring the full resources of the self to the computer" - Theodore Roszak

Today's digital world has created for us a digital experience to live in, one that tries to recreate every physical phenomenon within the vast capacities of its virtual self. More and more, children's experience of the natural world is confined to images on a computer screen. Multimedia encyclopedias, websites and computer simulation programs all enable children to visit and experience various types of environments at the click of a mouse. Instead of being formed by direct experience, children's perceptions of the natural world are shaped by the technology through which their experiences are mediated. In other words, **their real world experiences are being increasingly substituted by the creation of an alternative reality that is presented as being instantly accessible, controllable at will and one that stands for everything that exists in nature.**

What is more important is to however consider the effects of such an alternative reality not only from a practical standpoint but to our understanding of reality itself. The production of computer-generated representations has serious implications for our conceptualization of the relationships between the perceived image and its form of

production. Electronic representations have moved us past the concern for mechanical reproduction to an electronic format in which everything is reproducible digitally. With mechanical reproductions, there is still the object to be held. However, in digital reproductions there is no object, only the image. ***On the computer screen or the television monitor the image never exists as a single image. It is always scanned one line at a time. The image itself is an illusion. Not only must educators confront the transparency of technology, they also have to confront an image that is not real.***

Amidst our amazement of the wonders of the electronic age, we have forgotten the fact that the simple experience of being in nature is critical to the creative, intellectual and emotional life of children. Many scientists are now realizing the fact that direct observation and practical experience have a vital role in the child's thinking and overall development. In "The Ecology of Imagination in Childhood", Edith Cobb, a sociologist who has analyzed the lives of more than 300 outstanding individuals from the sixteenth through the twentieth centuries, concludes that a strong link exists between genius and the experience of being close to the natural world in childhood. Cobb asserts that ***creativity and constructive thinking are not the result of accumulated information***, but rather arise out of what she calls ***"a continued plasticity of response of the whole organism to new information and in general to the outer world"***. She mentions Einstein who acknowledged that his long walks in nature played a formative role in his thinking and geneticist Barbara McClintock among others such as Emily Dickinson, Julian Huxley, Lawrence Durrell and Margaret Atwood who attest to the importance of close contact with the natural world.

I believe that what Cobb terms as '***Aesthetic logic as being foundational to the child's creative insight***' can occur only within the child's environment and that ***technology if rightly appropriated can aid this process by situating itself within the child's learning environment as opposed to mediating its experience through artificial images.*** Thus, technology should allow for learning to occur from direct observation and action upon the world so that children are allowed to acquire a greater sensory awareness of their surroundings while acquiring a wealth of knowledge that they can draw upon all their lives.

iii. Interaction as opposed to creation with new technologies

In "*The Computer as a Convivial Tool*", Aaron Falbel writes about the use of computer technology within a view of education as a designed process or technical act that is performed on the learner. While explicating the active / passive distinction of learning through computers, Falbel mentions the fact that one must be wary of falling into the trap of saying that people are "active" when using computers, because they are pushing buttons or in some way responding to events on the screen, whereas they are 'passive' when say watching television because they are just looking at it. Indeed the computer environment as a medium largely restricts the process of active learning which should essentially involve creation as opposed to just interaction with new technologies such as video games, electronic storybooks, and "intelligent" stuffed animals. Moreover, what the children learn in a simulated two dimensional environment is decontextualized from the complexity and richness of real world objects, events and environments. Children's best learning experiences come through their act of being in the physical world when they designing and creating say sculptures out of clay or towers with wooden blocks where they have a tangible grip on reality. Their learning needs to be oriented to the world around them with its sights, sounds, smells, tastes and textures. It is this embodied learning experience that is fundamental to a child's creativity where they have a sensorimotor understanding of what an object is like and how it can be used in different contexts. No matter how sophisticated, the computer cannot provide these kinds of sensory experiences.

iv. Knowledge as Information and the speed of acquiring facts and concepts

Within the construction of our present digital technologies of the Information age, the sophistication and ubiquity of the modern machines gives rise to a view of knowledge that is commensurate to the amount of acquired information. Within the instructionist models underlying contemporary school, the role of technology is seen as a facilitator of a process of microdissection of a domain of knowledge into dozens, or hundreds or thousands of information fragments that are strung together as a curriculum. However, transmitting information through the systematic guidance of the curriculum is neither knowledge nor wisdom. Knowledge and the world are both

constructed and constantly reconstructed through personal experience. Each gains existence and form through the construction of the other. Knowledge is not merely a commodity to be transmitted, encoded, and retained, but a personal experience to be actively constructed. Within the accepted paradigms of today's information technologies, merely dispensing information cannot play a role in constructing knowledge. ***One needs to rethink these paradigms such that technology plays a greater role in facilitating knowledge construction within the learner as opposed to merely dispensing information. In order for this to occur, one needs to reconsider the appropriation of technology within instructionist models of learning and an information processing cognitivist view of the mind.***

C. Reassessing pedagogical technological practice - Towards a positive appropriation of educational technology

The value of an education ... is not the learning of many facts but the training of the mind to think something that cannot be learned from textbooks - Albert Einstein

i. Instructivist Design as an intellectual tradition guiding pedagogical technological practice

Instructional design, and indeed instruction in general in the United States, emerged from an objectivist tradition. Objectivism holds that the world is completely and correctly structured in terms of entities, properties, and relations. Experience plays an insignificant role in the structuring of the world while meaning is something that exists in the world quite aside from experience. Hence, the goal of understanding is coming to know the entities, attributes, and relations that exist. This very basic assumption has significant implications for instruction where the goal of instruction is to help the learner acquire these entities, attributes and relations to build a correct knowledge of the world.

The Instructivist design approach with its incorporation of objectivism has had a long lasting resonance with educators. It has been a tried and tested approach to appropriation of technology within pedagogical practice since it lends itself easily to curriculum objectives, defined and measurable outcomes and the traditional teacher-centered learning theories that reinforce a view that knowledge is independent of the learner. This approach clearly places the emphasis for learning on the dispenser of knowledge (i.e., teacher), and views technology as no more than a means of efficiently dispensing this information, an approach that leads quite naturally to a lecture format, a dualistic view of knowledge, and a passive learning experience.

The role of technology within an instructivist design approach has manifested in the form of Skinnerian teaching machines, programmed instruction, drill-and-practice and tutorial programs, computer aided instruction (CAI) based on the work of Alfred Bork and Patrick Suppes who emphasized rote memorization of facts and figures, technology enhanced Direct Instruction (DI) model for teaching that emphasizes well-developed and carefully planned lessons designed around small learning increments and clearly defined and prescribed teaching tasks, instructivist learning software such as *Integrated Learning System* from Jostens Learning, and *SuccessMaker* (individualizes learning for measurable success in grades K–8) developed by the Suppes' Computer Curriculum Corporation (CCC) that are designed to automate large portions of the established school curriculum and characterized by the controlled presentation of verbal or graphical instruction, prepared instructional materials such as electronic textbooks and powerpoint presentations where different forms of multimedia such as electronic text, graphics, sound and video are used to support the mastery of a particular concept or the more recent trend towards online publication of curriculum notes and lessons for distance education where the web is seen as a medium for the delivery of instruction.

Moreover, the objectivist epistemology of knowledge being separate from knowing has allowed for the process of Instructivist design to separate instruction from instructional content where the designers of instructional systems or content need not look at the actual instructional activities to see what is learned. Learning and understanding are seen as being composed of merely a knowledge base in the form of an "expert" model (which in technological terms consists of production rules, frames, slots, etc.) where particular stimulus events trigger particular productions. Hence, learning simply involves acquiring the information frames or production rules. A person's understanding can be fully specified by these exogenous descriptions. Within this view, designers then produce a

test that stands separate from the instruction and is designed to probe the knowledge acquired in an objective way. What this results in is a pedagogical process that is fragmented and unaware of the underlying principles that actually makes learning happen. As Instructivist design serves the needs of high usability, evaluation, predictability and structural clarity, instructivist systems are more common and are likely to have higher levels of general acceptance for that reason. Added to this is the argument that as evaluation methods tend to favor instructivist principles there is a greater push towards using systems that drill instruction and allow for quantitative measurement of the same.

The major outcome of Instructivist Design is the fact that it continues to exert a stronghold on our conception of knowledge that is seen as separate from the process of knowing, one that is gained objectively through the senses and that learning involves gaining truth that can be quantitatively assessed. Objectivist cognitive psychology, the model of the computer and how it is appropriated within the learning environment continue to significantly impact our perception about the nature of learning and the human mind. One gets the feeling that something is definitely not right and that it needs to change. With this view, I then look at some of the alternative approaches that have evolved within the practice of instructional design such that we can widen our spectrum of how technology can be more positively appropriated within pedagogical practice.

b. Constructivist Design as an alternative approach to pedagogical technological practice

"The world, as we perceive it, is our own invention" - Heinz von Foerster

It is not that the Instructivist Design approach has evolved without any criticism. Theorists and practitioners within the field of instructional design have long asserted the fact that both knowledge and the world are actively constructed by the learner and that technology should be seen as playing a role in scaffolding such a learning process instead of objectively imposing facts and knowledge on the learner. These assertions have evolved within the framework of Constructivist Design that is derived mainly from the works of Piaget, Bruner, Vygotsky and Papert. However the ideas behind Constructivism date back to the work of Vico (early 18th century), Jean Rousseau and probably the most influential advocate against the educational framework of memorization and recitation, John Dewey who argued that "education is not a preparation for life, it is life itself".

Although, constructivism as a theory is attributed to Piaget who articulated mechanisms by which individuals construct new knowledge from their experiences, constructivism as a pedagogical technological practice did not evolve until the works of **Robert Davis - Socratic Interactions and Discovery Learning through PLATO (1950)** influenced by the Discovery Learning approach of Bruner that emphasized exploring, experimenting, doing research, asking, questions, and seeking answers through a learning process focusing on high level thinking and on intrinsic rather than extrinsic motivation. Davis with his focus on the child's experiences wanted to teach children mathematics in a style that emulates a mathematician's experiences. He saw the potential in computers to guide children towards constructing their own knowledge by building on their natural curiosity and allowing them to discover the laws of mathematics for themselves. Similarly, **Suchmann's Inquiry training Model (1962)** was influenced by Piaget's concepts of constructive learning, active participation, and the concepts of disequilibrium through which learners are internally motivated to learn

Seymour Papert - LOGO (1967) is probably the most widely cited of Constructivist Design practitioners who viewed computers as a tool that should be controlled by children and its open architecture that would allow children to construct their own knowledge. Thus, LOGO was invented as a programming language that allowed children to construct their own knowledge. Based on the success of the original LOGO, Microworlds as an environment in which children can explore and construct their knowledge was conceived by Papert. Turtle Geometry is one of the original Microworlds in which children as designers, constructors, and explorers could get to know this learning environment and restructure it or even add another Microworld to it.

Today's constructivist design practices are evolving in the form of computer based **Constructivist Learning Environments (CLE) - Duffy, Cunningham, Jonassen** which are beginning to use the networked computer and the internet as more than just a medium of delivering instructional content. For example, WebQuest is an inquiry

oriented CLE that presents student groups with a challenging task, provides access to an abundance of usually online resources and scaffolds the learning process to prompt higher order thinking. Students benefit from being linked to a wide variety of Web resources so that they can explore and make sense of the issues involved in the challenge.

iii. Critical Assessment of Instructional Design approaches

Although constructivism as a theory has long challenged the Instructivist principles, practical realizations of the same have been few and far between. Constructive Design as a practice hasn't been applied outside the adopted paradigms of the modern computer such as the desktop model and the subjection of experience to its artificial screen reality, paradigms that impose severe limitations to constructivist applications. Moreover, such a practice has approached the process of active learning only in terms of programmed thinking, problem solving and logico-mathematical thought processes initiated by the learner which can be seen with Davis's PLATO system which was meant to teach children mathematics by emulating a mathematician's experiences or Papert's LOGO where the learner thinks in terms of programmed sequences that control a turtle that draws graphics on the screen.

The point that I wish to bring out is that Constructivist Design operating within the model of the desktop computer has not been able to adequately translate constructivist principles such as active learning, meaningful learning within and across contexts, learning through one's experiences or providing the learner with multiple perspectives that challenge his conceptualizations of the world into practice, thereby restricting the learner's activity to programmed thinking and vision as the dominant perceptual mechanism of the learning process. Consequently, there hasn't been an approach within Instructional Design that is theoretically grounded in the fact that learning is a process of one's embodied interaction with the environment and that knowledge cannot be separated from the act of being. The role that senses play in a child's intellectual development has not been adequately considered, the importance of which has long been advocated in early Montessori schools and by prominent thinkers such as Jean Rousseau.

Moreover, the mode of thinking in the active learning process that I consider of greater importance is one of higher order thinking such as subjunctive thought that is fundamental to a child's creativity and one that enables it to acquire the larger meaning of things and allows for different interpretations of what is ordinarily conceptualized and perceived, something that the psychologist Edward De Bono calls as lateral thinking as opposed to programmed thinking. I thereby see a necessity to approach the problem of Instructional Design in these terms so that a more complete realization of what has been left out becomes possible.

iv. Theoretical Framework guiding my Design Approach

a. Adoption of a 'Grounded Constructional' Design

In "*The Case for Grounded Learning Systems Design*", Michael J. Hannafin mentions that a good deal of instructional design practice has evolved as a kind of procedural and media-production craft rather than a grounded process. Since models derived from this practice also reflect an underlying conceptualization of what it means to learn, to understand, and to instruct, it is critically important that designers of such systems have a theoretical reflexiveness about the underlying assumptions of their systems that affect the learner. As Bednar, Cunningham, Duffy, and Perry have stated in *Theory into practice: How do we link it?*, "Effective instructional design is possible only if the developer has reflexive awareness of the theoretical basis underlying the design. It emerges from the deliberate application of some particular theory of learning".

Accordingly Hannafin explains two approaches to the concept of grounded learning system's design, one is *Grounded Instructional Design: A Directed Learning Environment* where the role of the system's designer is to provide the learner with an environment which helps him accomplish various tasks principally by decoding the established meaning of various objects and events. The other is *Grounded Constructional Design: A Situated Learning Environment* where objects and events have no absolute meaning. Instead, the learner interprets each

and constructs unique meaning based upon individual experience and evolved beliefs. ***The design task, therefore, is one of providing a rich context within which meaning can be negotiated and ways of understanding can emerge and evolve.*** Since I have argued vehemently against an Instructivist Learning, I shall adopt the Grounded Constructional Design approach as a starting point.

b. Deriving the theoretical approach

i. Constructing definitions of knowledge and learning

I derive my theoretical approach to pedagogical technological appropriation from two interdisciplinary theories of research that I believe have more in common than when considered in isolation. One is more a theory of learning called ***Constructivism*** and the other is more a theory of cognition called ***Embodied Cognition***. However the fact that they both view the nature of knowledge as being essentially of active nature makes them interesting to pursue for the purpose of guiding my design approach. Moreover, they complement each other in the sense that while constructivism does not elaborate on the 'active' component of knowledge, embodied cognition can be seen as completing the picture with this activity being grounded in the learner's embodiment and sensorimotor experiences.

However, before deriving my approach I wish to illustrate through an example, how knowledge can be seen as being constructed by the learner. Consider for example, the vase of Rubin. What can we see? Certain people would see a vase whereas others would see two faces. This example shows that when confronting the same information, people construct different knowledge. ***However, merely seeing this example as an illustration of constructing two different versions of the same information is an understatement of how humans construct knowledge.*** It is an example two start understanding knowledge construction, not the complete picture. When confronting this information in the 2D plane of the computer image or paper, one can place all the basis of one's argument in terms of visual representations and an objectivist cognitivist would be more than happy to write a neat computer program that essentially separates the black and white pixels and churns out two different versions of the same image claiming that, this is how humans construct knowledge. However, constructing knowledge in the multi-dimensionality of the real world is an entirely different ballgame.



In the real world, it is impossible to separate the construction of knowledge from the act of being. We actively construct knowledge through our perceptual-motor capacities and our dynamic interactions with the environment. In other words, we construct knowledge through our unique embodiments, the capacities of which are in turn shaped through these interactions. Knowledge thus has to be seen in terms of our evolving sensorimotor representations as opposed to restricting these representations to just a fixed set of perceptual capacities. Thus, how we would construct knowledge when confronted with an object or event in the real world would be entirely different. To explain this further, let's consider the vase of Rubin again. Given the fact that my sensorimotor representations exist, what I perceive is not just two faces or a vase for that matter, instead I elicit representations of what these faces or vase personally mean to me and how I know them through my interactions in the real world. For instance, these two faces might invoke an image of two debaters in a public setting that I happened to experience first hand. My sensorimotor representations that evolved as I applauded one of those debaters or roamed about in the physical space or shook hands with the one who happened to win, are all associated with this

image. ***My knowledge of two faces is then not one of the image itself or one that exists solely as a mental representation, but one that was constructed through my embodiment.***

The above preliminary understanding of knowledge was based on but a simple example. Let us see how we can theoretically achieve a similar definition of knowledge. According to the constructivist ideas of Piaget, knowledge is not out there, external to the individual and waiting to be acquired. It is neither wholly preformed within the individual and ready to emerge as the individual develops. Instead, knowledge is invented and reinvented as the individual develops and interacts with the environment surrounding him or her. These are ideas that a reader is probably already familiar with over the course of reading this thesis. What is of greater importance is the fact that ***Piaget believed that this knowledge exists and is organized as cognitive structures or schemata. However, there is inadequate literature to understand if Piaget as a cognitivist constructivist attributed anything other than mental significance to these cognitive structures. Subsequently, cognitive structure as a concept has been widely interpreted in the literature on constructivism as one that exists in an individual's mind to organize and interpret information (Sanrock, 2001, p. 49) and this is where cognitive structure as a concept leaves out the important role of embodiment that I just described and hence I would like to extend this concept.***

In order to do so, let's come back to Piaget's conception of the child development process which is driven by a continuing equilibrium between the two complementary processes of ***assimilation*** and ***accommodation***. In terms of cognitive schema, Piaget defines ***assimilation as a process through which the child imposes an existing schema on the world through play*** while ***accommodation is defined as a process through which the child modifies the schema to fit the world through imitation***. However, both play and imitation are activities which are not solely constrained to the mental structures of the child; instead they are carried out as a result of the child's being and interaction with the environment. ***Hence, the cognitive structures that develop as a result of these processes cannot be defined in terms of mental schemata alone, but more in terms of the child's body image i.e. its conscious representation of some sensory-motor aspects of the body, bodily schemata i.e. its unconscious awareness of the body, extended bodily schemata i.e. bodily schemata extended using tools which in case of the child maybe simple objects such as blocks or marbles that it plays with and its physically grounded action and behavior upon and in relation to these objects and events in its environment.***

And this is my claim that extends or clarifies the Piagetian concept of schemata in terms of the child's physical activity and embodiment. To support this claim, I cite the "***physical grounding hypothesis***" as the most important and substantive claim of the Embodied Cognition paradigm which says that the contents and operation of the mind are grounded in an agent's physical characteristics and embodied experience. I also cite the substantial theoretical and empirical work in the field of imitation research, examples of which are mirror neurons, active imitation, imitation models such as Active Intermodal Matching (AIM) and mappings between sensorimotor primitives and executable motor programs, all of which support the idea of representation in terms of the strong coupling between perception and action. It is then with this claim supported by the above citations that I would like to extend or re-define the Piagetian concepts of schemata, assimilation and accommodation and arrive at more substantive definitions of knowledge and learning.

1. Physically grounded cognitive structures or schemata (PGCS) is a concept or framework that exists in terms of an individual's sensorimotor representation as a result of his or her embodiment to organize and interpret information. This definition is compared to "Cognitive structure is a concept or framework that exists in an individual's mind to organize and interpret information (Sanrock, 2001, p. 49)"

2. Definition of Knowledge based on 1 - Knowledge is physically grounded cognitive structures (PGCS) an individual constructs about the new information on the basis of his or her own embodied experiences and the interaction with the environment.

3. Definition of Assimilation based on 1 - Assimilation is a process in which an individual imposes an existing physically grounded cognitive structure (PGCS) on the world. This process more specifically in terms of a child is facilitated through play.

4. **Definition of Accommodation based on 1** - Accommodation is a process in which an individual modifies the physically grounded cognitive structure (PGCS) to fit the world. This process more specifically in terms of a child is facilitated through imitation.

5. **Definition of Learning based on 1, 3 and 4** - Learning is a process involving a continued equilibrium between the two complementary processes of assimilation and accommodation through which individuals construct and transform physically grounded cognitive structures (PGCS)

ii. Substantiating definitions through theoretical tenets of constructivism and embodied cognition

Constructivism	Embodied Cognition
1. Learning is the active process of constructing rather than passively acquiring knowledge	1. The way we actively conceptualize and categorize knowledge is based on the way we are embodied.
2. Learning takes place in contexts (Schunk, 2000)	2. Cognition is constructed as an interaction between the embodiment of the organism and its environment
3. Learners construct knowledge through their situated experiences (Schunk, 2000)	3. Cognition depends on the kinds of experiences that come from having a body with particular perceptual and motor capacities that are inseparably linked
4. Learning occurs through multiple perspectives that challenge the learners' thinking (Duffy & Cunningham, 1996; Jonassen, Mayes & McAleese, 1993)	4. Sensorimotor experiences that serve as the basis for how an organism understands a specific interaction inform its subsequent interactions

c. Design implications for a constructivist learning environment

a. Activity and Senses

- a. The design task should consider the child as an active learner.
- b. The primary conditions for this active process are:
 - i. Allowing for this activity to be grounded in the child's embodiment as opposed to merely mental processes
 - ii. Allowing the child to create something in the process of learning as opposed to mere interaction
 - iii. This creation should have personal meaning to the child and invoke reflexivity of its own role in the knowledge construction process
 - iv. The objects and components of the activity should have a high ceiling to sustain the child's enthusiasm in the learning process
 - v. The child's sensorimotor representations should evolve as a result of his visuo-tactile sense of the world

b. Environment and Experience

- a. The design task should not make an artificial screen based reality as the dominant sensory experience
- b. The design task should allow for a rich multi-sensory learning experience
- c. This experience should occur in the child's physical learning environment
- d. Technology should be embedded in such an environment

c. Lessons Learnt

- a. The design task should not impose facts and concepts on the learner
- b. The goal of the lesson should not be a binary one, instead one involving the learner in a rich process
- c. This process should be one in which meaning and understanding can emerge and evolve
- d. For such meaning and understanding to evolve, the design task should:
 - i. Should allow parts to be seen in terms of wholes i.e. macroscopic
 - ii. Should allow for establishing new relationships between parts to form new wholes

- iii. Should impart the understanding that these parts, wholes and relationships can have different meaning in different contexts

d. Mode of thinking and Technology Scaffolding

- a. The design task should scaffold the higher order thinking processes of the child such as subjunctive thought, the primary conditions for which are:
 - i. Allowing for lateral thinking as opposed to programmed thinking
 - ii. Providing multiple perspectives that challenge the learner's conceptualization of the world
 - iii. Since learning according to Piaget occurs through the complementary processes of assimilation and accommodation,
 - a. The child should be allowed to impose its existing cognitive structures through assimilation
 - b. At the same time, the design task should provide stimuli to the child so that it can accommodate new information
 - iv. Technology scaffolding in terms of multiple perspectives and stimuli should build on the child's past constructions

e. Context and Transferability

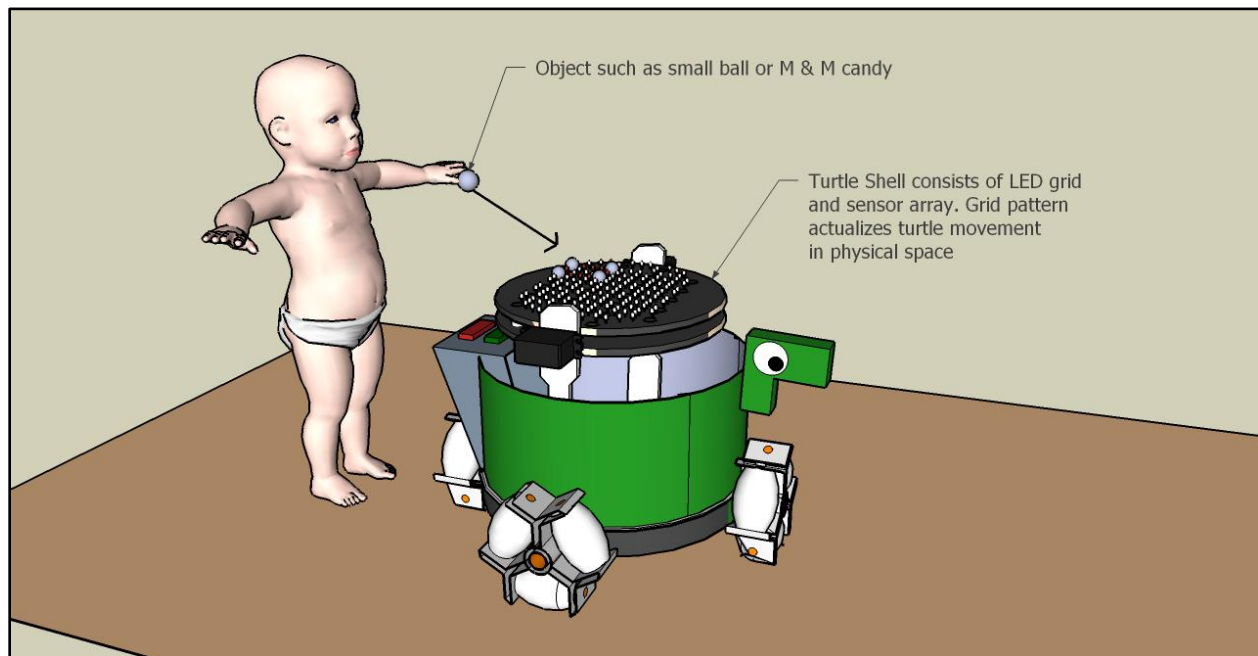
- a. Learning should occur within a personally meaningful context
- b. Lessons learned within one context should be transferable to as many different contexts as possible
- c. Such a transferability should allow for new modes of interpreting knowledge and experiences

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Section 2: Project - M-CLE: An Embodied Constructivist Learning Environment

A. Overview and Turtle Narrative



The child controls a Robotic Turtle by creating patterns of its shell by using objects such as small balls or M and M Candies. Each object is a vertex in the pattern that actuates an underlying sensor that maps its position with respect to other vertices. As soon as the child creates a second vertex a link is created with the first. So two vertices form a line. The child uses this basic relationship to create more complicated patterns such as triangle, square or others which have personal meaning to it. The turtle narrative goes something as follows:

“The turtle is unintelligent without its embodiment and its shell is occasionally destroyed by the world who enforces it a belief that its mind is alone sufficient to survive. But the turtle knows that it cannot move without its shell and it cannot think without its body. So it is asking for help. The child helps the turtle to complete its shell by fixing its broken parts which are small objects such as balls or m and m candies that the child normally would associate with other things. The child then places the first object and tries to help the turtle. But the turtle has a larger mission for the child other than just helping it to complete its shell. The turtle makes the child realize that it is not about completing the shell but how it completes it and what it learns during this process. The mission of the turtle is to help the child’s creativity to develop by providing it with multiple perspectives, seeing parts in terms of wholes and stimulating it to see the larger meaning of things. This is how the turtle sees learning to be”

This learning is then accomplished in three modes mainly that of assimilation and accommodation

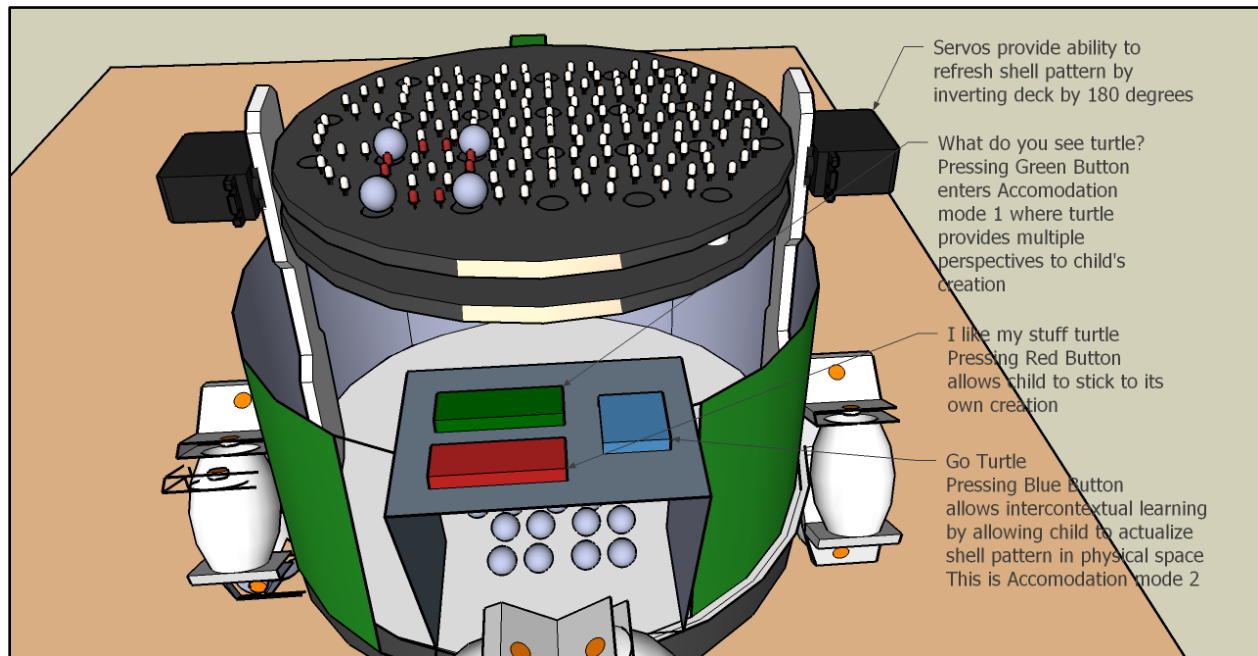
Assimilation mode – The child imposes its existing physically grounded cognitive structures to create personally meaningful patterns. As described theoretically, these cognitive structures are physically grounded since the child uses its hands to place objects on the shell and so these structures represent a relationship between its physicality and the spatial arrangement and relationships between objects on the turtle shell.

Accommodation mode 1 (Multiple perspectives, Provocation) – The turtle stimulates the child’s creativity by providing it with multiple perspectives of relationship between objects. Thus it creates new patterns (see section on Turtle pattern creation). This mode may be automatically imposed by the turtle or when the child asks the

turtle a simple question of “What do you see turtle” by pressing the large green button. If the child likes what the turtle shows it then it can reconfigure its creation or build on top of it.

Accommodation mode 2 (Intercontextual Learning) – Pattern transfer to physical space

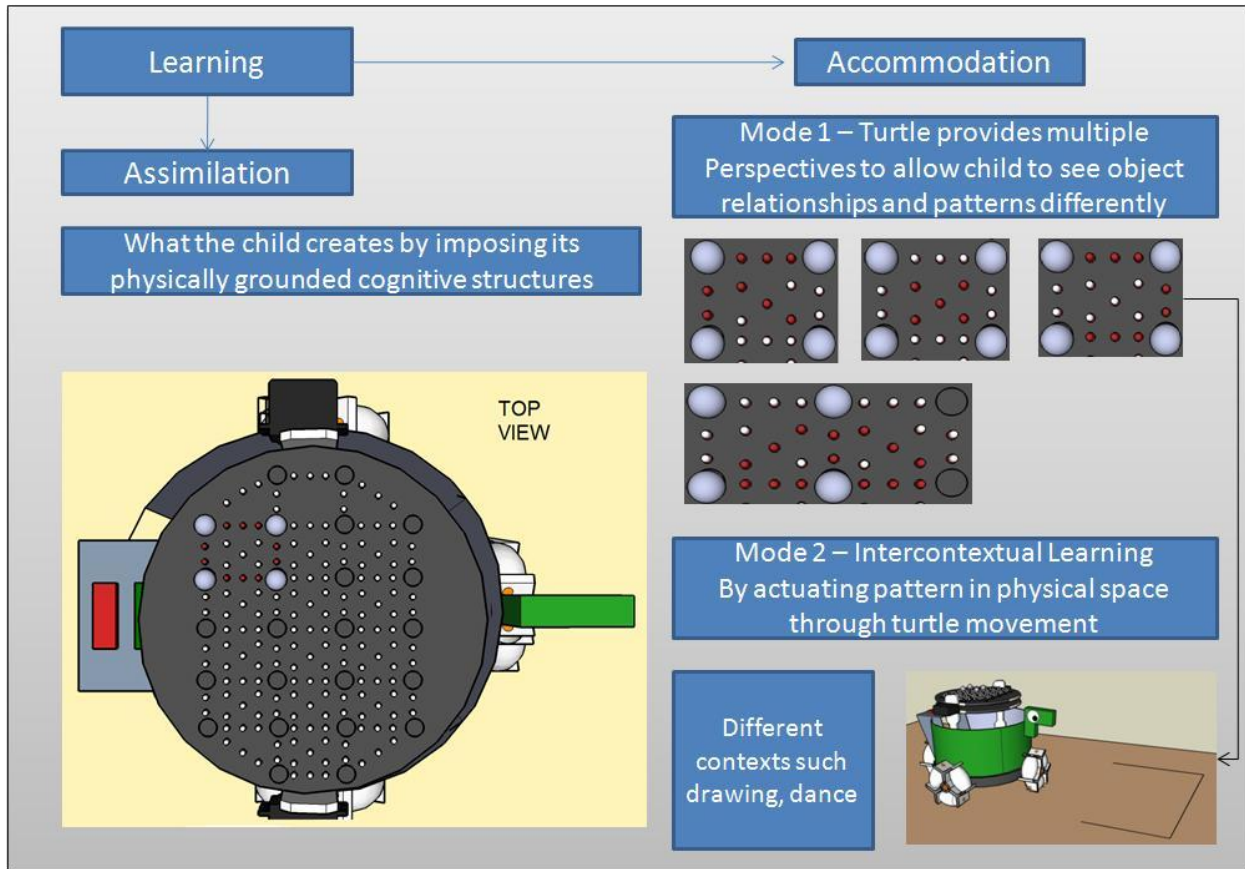
B. Turtle Components



1. Servos – Allow for shell pattern to be refreshed by inverting deck
2. Turtle Deck (Top) – Contains holes for objects
3. Turtle Deck (Bottom) – Contains LEDs and sensor array
4. Devantech Geometric Sensor – Allows for translation of patterns to physical space using N,S,W,E
5. Green Button – What do you see turtle ? - Enter Accommodation mode 1
6. Red Button – I like my own stuff turtle
7. Blue Button – Go Turtle – Enter Accommodation mode 2

See next page

C. Learning through assimilation and accommodation modes



D. Comparison to LOGO

1. Activity and Senses

Embodied versus visual

2. Representation

Sensorimotor versus visual (Physically grounded cognitive structures)

3. Mode of Thinking

Lateral versus programmed

4. Context and Transferability

Across different contexts versus within computer screen

5. Lessons Learnt

Creativity versus math and geometry

6. Environment and Experience

Physical space versus computer reality

7. Technology Scaffolding

Robot stimulates the child as opposed to child just controls turtle to draw graphics on screen