INTERACTIVE SPACES:
SPACE OF INTERACTION

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ABSTRACT:

Interactivity is trans-disciplinary, fusing aspects of both human behavior and computer technology. Successful human to computer interaction requires mastery of both domains. However interactivity considered through the lens of teaching and learning where the novice student needs to understand and master aspects of both domains can be problematic. Typically the two key obstacles to learning in interactivity are that understanding of behavioral aspects are often diverted by technical and logical processes; and conversely where the human behavior is well studied but insufficient attention is paid to the technological implementation.

This paper outlines how changing the mode of the knowledge acquisition in the teaching of interactivity in *physical computing*[1] from teaching to learning in a *constructionist* type framework, strengthens and improves the quality of the student's learning experience. This epistemological shift is contextualized in framework that references 'play' as a fundamental human action that can be aligned with the approaches outlined by Seymour Papert and other seminal originators in this field.

Keywords: Interactivity, Play, Tolerance

1. SPACE OF INTERACTION

Interaction as a field of learning is a relatively new and immature domain that is trans-disciplinary in nature. Increasing popularity and technical capability in interactivity generates many possibilities for design. However, despite the recent seamless integration of different technological platforms incorporating interactivity, the sophistry of many interactive systems and their manifestations has proved a barrier to many who might otherwise have an interest in the field. For example many proprietary systems on mobile devices carefully embed their systems to prevent users from accessing and modifying their systems.

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[1] Physical computing is the design and construction of interactive computing systems using microcontroller computers, sensors, electro-mechanical devices and actuators that can be programmed to sense and respond to the analog world.

Because of these issues the field of *physical computing* (see Igoe and Sullivan 2004) is an attractive framework for teaching interactivity. Originating as a hobby based platform, its open source framework together with the availability of a vast array of resources as well as the relatively low technology base make *physical computing* highly accessible to learners and other users. As *physical computing* evolves into a discipline in its own right it has become a growing field in teaching and learning environments, in both engineering and design schools but also in secondary schools and other educational contexts. During this time the evolution of microprocessors from Basic Stamp, Arduino, to Raspberry Pi, reveals the tendency for increasing applicability and wide spread usage.

Further, *physical computing* allows learners to not only conceptualize interactivity but to construct this interactivity as a physical human to computer system that they can test and play with. This is especially applicable in the fields of physical, embodied, tactile and tangible interaction allowing exploration in physical space with the full range of body motion and its actions, and the whole range of senses (McCullough, 2004), in other words physical computing is able to form interactive immersive environments (Figure 1).

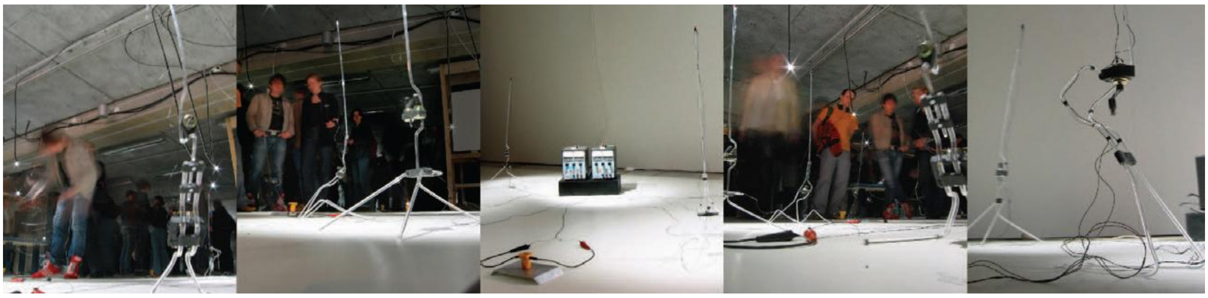

Figure 1: Architecture and Urban Research Lab, KTH Stockholm 2001: Sentinels

This makes *physical computing* distinct from other forms of interactivity that are predominantly screen and information based (although we should note the convergences of the different forms of interactivity in recent years). Advocates claim that our interaction with physical objects can provide a sensory richness not replaceable by GUI screen based interactive systems; suggesting that when we see, hear and touch real-world objects we interact or engage both cognitive and perceptual skills. As Paul Dourish says: “One sees the environment not just with the eyes but with the eyes in the head on the shoulders of a body that gets about.” (Dourish, 2004, p117). The potential for learners in *physical computing* to play and learn by constructing their own knowledge and experience (physically, conceptually and in terms of skill sets) in this field is high, with each individual’s active learning experience providing a unique reference point and a basis for real knowledge to emerge (Figure 2). In terms of intended learning outcomes this approach can successfully provide learners with a deeper understanding of the principles of interactivity, HCI, feedback systems and media ecosystems (see Hasdell 2006, 2010).

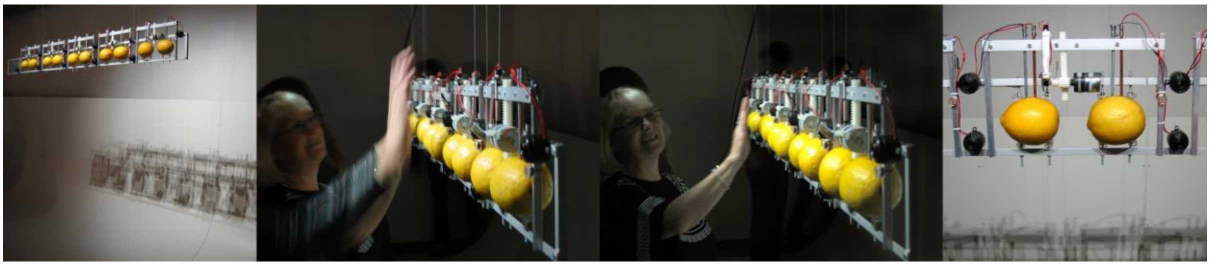

Figure 2: Architecture and Urban Research Lab, KTH Stockholm 2001: Singing Lemons

However, *physical computing* still requires the integration of number of divergent skill-sets; technical and logical, behavioral understanding, interface design, system design and also in physical design skills. These or subsets of these skills need to be mastered before the interactive designer can even begin to explore or play with the system they conceive. Whilst this is not an issue for experienced interaction designers, it can be a hurdle in terms of accessibility for new designers. The learning path is steepest particularly for those who have no or little technical background in electronics or programming. For example the steps of basic circuit making even in its simplest forms requires understanding of voltage, current, resistors and circuit design. This is compounded by the need for actuators or other output devices which may run on a different voltage to the basic controller circuit. A similar issue happens with the programming environment which in many cases can be challenging for a novice to understand, in which a simple syntax error can make a process inoperable. From my experience, the design processes considered as an active learning process, is stifled during this period as the logical needs to understand the systematic (technical) factors take over (Figure 3).

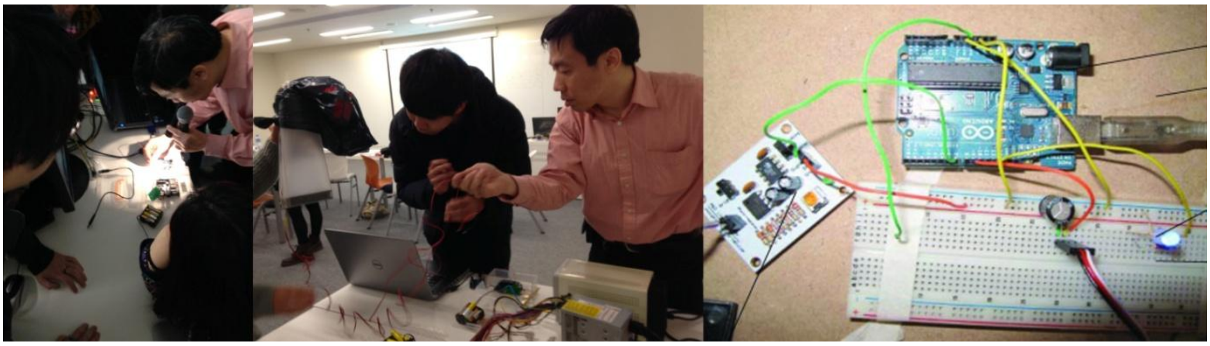

Figure 3: Interactive Spaces: Technical obstacles Arduino, breadboard and programming environment.

It is precisely at these moments that the learning path switches from learner driven knowledge construction modes to passive instruction modes that needs to be delivered by the teacher who possesses the required technical knowledge. This disrupts the flow of learning for the student and requires them to move from exploration or design oriented processes to analytic thought processes. Each technical stage, be it programming, circuit making or input and output typically requires one or two teaching sessions to instruct, meaning that a conventional approach to a *physical computing* project may require between 7 or 8 sessions to complete.

My approach[2] to this problem adjusts three aspects of teaching hands-on interactive *physical computing* in order to refocus the learning process to one in which the learner has a more continuous or obstacle free pathway for their construction of knowledge.

ADJUSTMENT 1: REDUCE TECHNICAL OBSTACLES

The reduction of complexity in technical components of the *physical computing* system is effected through the use of the Device Interface Board (Figure 4: designed by Kinsun Tung[3]). This is a custom made electronic board incorporating a microcontroller and different output modes aimed at simplifying the making of interactive devices and installations. Most existing microcontroller systems still require additional steps such as the making of electronic circuits and construction of relays to allow the controller to control external output devices. In comparison the Device Interface Board does not need these, thereby removing a significant obstacle allowing users to more quickly test their physical interaction. Its ease of use allows users to focus on design needs and "what to do" rather than "how to do," encouraging learning knowledge construction in a more self-directed and intuitive way.

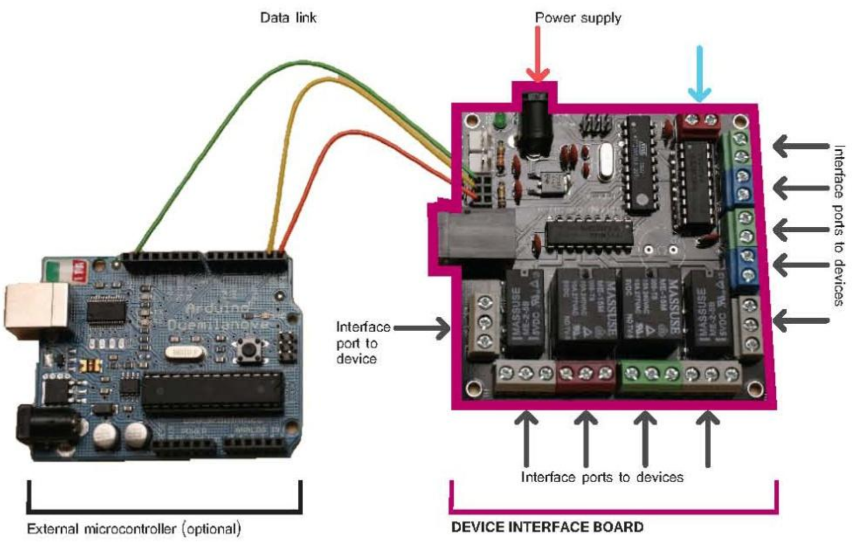

Figure 4: Device Interface Board and connection to Arduino (optional).

ADJUSTMENT 2: SIMPLIFICATION OF OUTPUT SYSTEMS

Secondly, by employing quick and intuitive DIY low pressure inflatables[4] (Figure 5), constructed from computer fans, plastic bags, tape and sensors, learners can quickly master the analog

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[2] Having taught interactivity since 2001 in different contexts including Sweden, Canada and in HK, I have had the opportunity to evolve my teaching process in physical computing in three main stages. Firstly as a time and resource intensive technocratic approach. Secondly using toys as starting points to hack and adjust into responsive systems. And thirdly as knowledge constructionism based approach outlined here that shifted emphasis towards the learner.

[3] Kinsun Tung co-taught with the author in Interactive Spaces course since 2010. The Device Interface Board was developed specifically with this kind of teaching in mind.

[4] The development of inflatables derives from the 1960s counter-culture movement (Dessauce 1999): a temporary, flexible system, tapped into the emerging DIY movement of the time exemplified by the *Whole*

principles of interactivity. At the same time this simple system amplifies and animates effects. The motivation for using low pressure inflatables is twofold. Firstly as an instant DIY system composed of plastic cells, fans and tape, they can be quickly made, adapted, and changed.

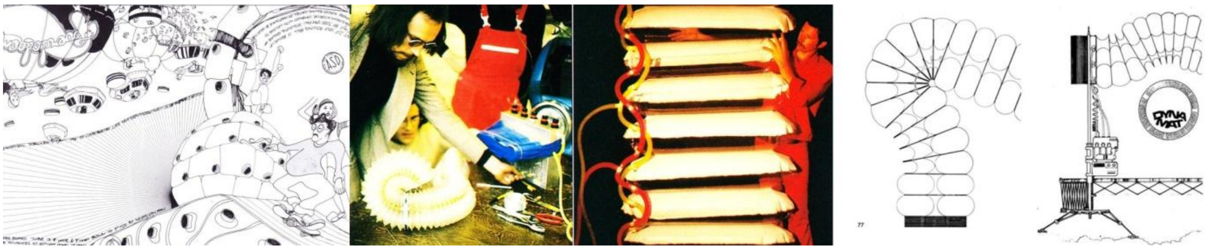

Figure 5: Mark Fisher Dynomat: Architectural Association graduation project 1970s.

Secondly the learner can construct a very low tech analog system that can 'actuate' responsive and interactive behaviors through inflation and deflation (input and output). The resulting inflatable can have many states; deflated, partially inflated and fully inflated, with gradations in between, with corresponding qualities of softness to hardness, non-structural to rigid (Figure 6). In this way the inflatables can be understood as more like the elements we find in natural systems, muscles, tendons, cartilage, cell walls and skin.

Figure 6: Interactive Spaces: Low pressure inflatables.

ADJUSTMENT 3: NON-FUNCTIONAL INTERACTIVITY

Thirdly by removing to a large degree any emphasis on means-end functionality, prescribed use or utility value, the learning path can be more playfully explorative. The motivation of the individual learner is often higher in these instances than when answering prescribed problems and the innovation potential is also higher. Instead individuals formulate their objectives and any functional or utility aspects as a part the process of their construction of knowledge.

Earth Catalogue. Founded by Stewart Brand in 1968, it presented instructions on how to make your own inflatable spaces. It is notable that in 1968 Brand worked with Douglas Engelbart - who invented hypertext and the mouse - to produce *The Mother of All Demos* a computer demonstration aimed at manifesting Vannevar Bush's *Memex* device. Key computer innovations were shown that were later adopted by Apple and Microsoft. Similarly, the art group Ant Farm conducted a number of events making large scale inflatables and produced its own instruction manual *Inflatocookbook*. During this time Archigram (*Cushicle* (1964) and *Suitaloon* (1967)), Mark Fisher, Coop Himmelbleu and others, were active in this field. In recent years interest in inflatables reemerged.

The three adjustments, evolving out of previous interactive teaching schemas, were conceived in order to make access to interactivity in *physical computing* easier and faster for the novice learner. The reduction in the number of steps and complexity sets in place a more intuitive set of elements that can more easily be understood and mastered without technical obstacles, reducing by half the amount of teaching instruction needed and the time needed to master basic interactive principles. More importantly I have found that it enables the novice learners to more clearly engage in individual processes of knowledge construction. Furthermore this encompass an idea of teaching interaction as less of a technocratic process with a directed or prescribed set of learning sequences but more of an open ended exploration of possibilities and potentials of interaction with little or no pre-determined outcome. In this way the work does not originate from a series of functional ideas and technical resolutions of those conceptual steps but is driven from an action and exploration based approach that attempts to shift the emphasis of the interactive teaching away from technical problem solving and towards constructive play. This approach has evolved through my teaching course called Interactive Spaces for novice undergraduate students (Figure 7). The course originally began by looking at responsive adaptations of toys and gradually evolved by reducing the technical complexity to bring the interactivity more into the foreground.

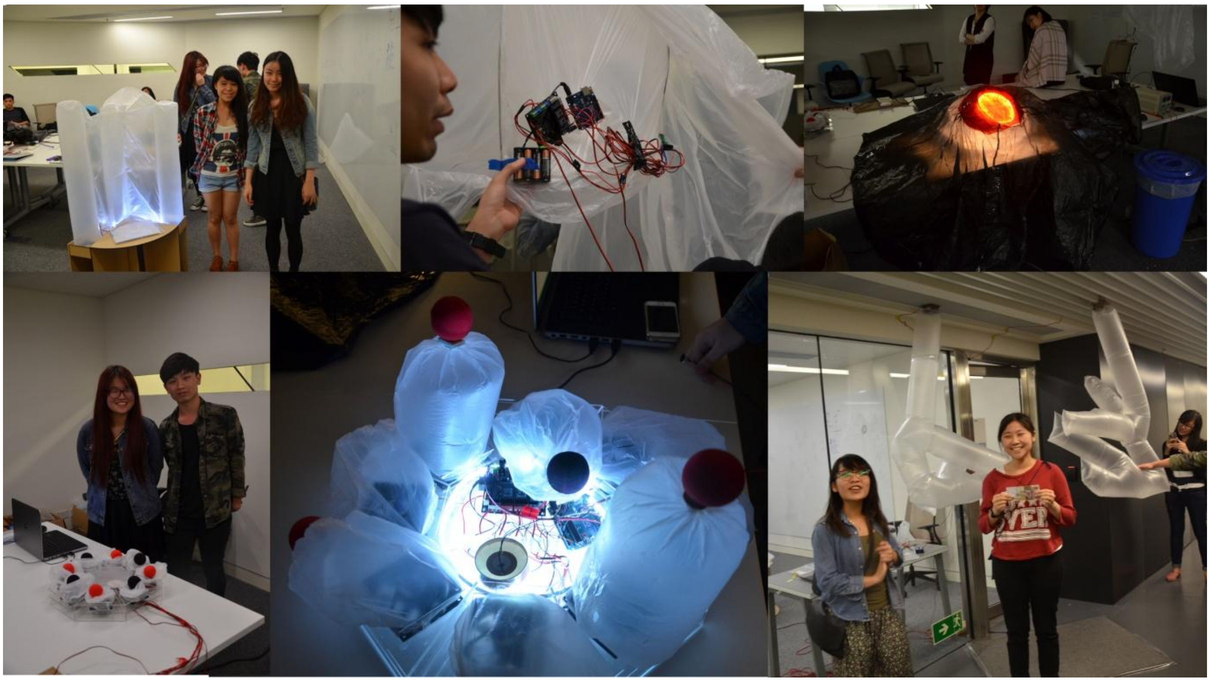

Figure 7: Interactive Spaces 2013: various works.

Further exemplifying some of the potentials of these changes is a one day workshop called Interactive Inflatable Monsters organized and conducted by the author together with Kinsun Tung. The workshop with 27 secondary school students who constructed a number of interactive inflatable monsters that could breathe, pulsate, wobble, grow and shrink according to various inputs from the users or viewers. Small groups of 3 students each made one monster to their own design from garbage bags and tape to make low pressure inflatables with computer fans, bathroom fans or truck driver fans to provide air pressure for inflation. No technical knowledge of interactivity was necessary. Interactivity was provided through inputs of light and touch which allowed the fans and LED lights to respond in various ways, and the Device Interface Board microprocessor controlled the inputs, outputs timing and sequences of the system according to the wishes of the participants. The Monsters (Figure 8) were activated by viewer's interactions including shining a torch and various simple actuators such as the pushing or stepping on a pressure switch.

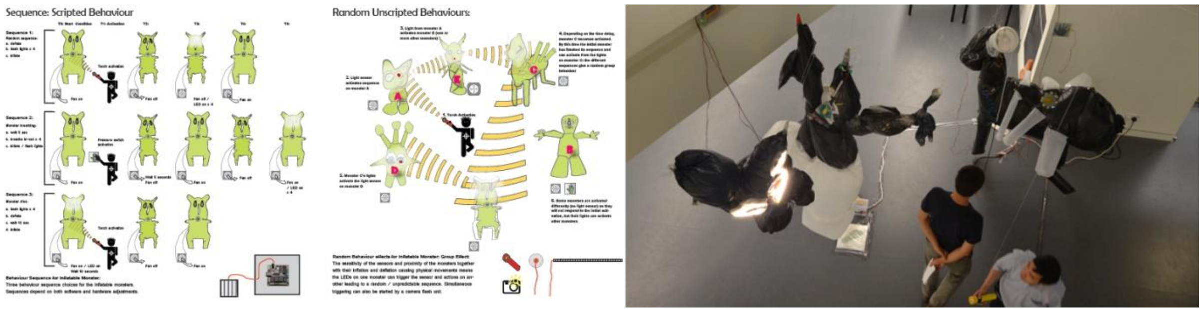

Figure 8: Interactive Inflatable Monsters 2013: schema diagram and outcome

2. CRITICAL CONTEXT: SPACE OF PLAY

Fundamental to the outlined approach to interaction learning is the notion of play. Play has many context dependent meanings; however my interest is in two interrelated meanings: firstly; play as an open ended (without bounds) means of exploring and interacting; and secondly, play meaning latitude or room to operate - or in other words - a tolerance in the system (Figure 9). For Johan Huizinga, play is a fundamental human activity standing "…outside 'ordinary' life as being 'not serious' but at the same time absorbing the player intensely and utterly." (Huizinga, 1955, p13) Huizinga elaborates play's social basis as dependent on interaction (see also Ha and James, 1998). The issue of play clearly overlaps with the origins of interaction design in the field of developmental psychology. Jean Paiget's work on cognitive learning processes and the importance of play in the development of the child's creative mind, is a critical point of reference: "Play is derived from the child's working out of two fundamental characteristics of his mode of experience and development. These are … attempts to integrate new experiences into the relatively limited number of motor and cognitive skills available at each age." (Piaget 1962, p121). Paiget structured these into his *Constructivism* schema in which each learner - individually and socially –constructs knowledge as he or she learns; an active form of learning in opposition to the instruction centric form of learning in which the teacher transmits knowledge the passive receiver students. *Constructivism* epistemologically shifts the emphasis from standardization to individualism and creativity, knowledge acquisition is interactive and context dependent and is a continuous creative process: "... education means making creators... You have to make inventors, innovators—not conformists" (Bringuier 1980, p. 132).[5]

[5] Comprehensively discussed elsewhere, a variety of related cognitive theories including social constructivism exist; Lev Vygotsky argued that a child's learning was preceded by a socio-cultural context defining the learning environment, and that this can be understood as a form of co-construction of knowledge.

Figure 9: Interactive Spaces 2011: Play and toys

2.1. COGNITIVE THEORY: CONSTRUCTIVISM

As noted elsewhere, Paiget has been often cited by early progenitors of educational computer learning environments and interaction theorists. His cognitive framework as a model for learning and knowledge acquisition, was referenced as a conceptual framework for computers to self-learn (artificial intelligence: AI) emerging out of Research Centres during the 1960s and 1970s. Similar developments also explored and conceptualized user interfaces using cognitive theory and behavioral studies as a conceptual framework, furthering the work of Ivan Sutherland's *Sketchpad* (1963), Douglas Englebart's mouse (1965) or Vannevar Bush's *Memex* (1936) (Figure 10). Like Paiget, the cognitive theorist Marvin Minsky also had an impact on the emerging field of interaction, as co-founder of MIT's Artificial Intelligence Lab, he developed the first head mounted graphical display. In contemporary discussions, cognitive theories continue to influence the fields of interaction, for example Vygotsky's context driven activity theory was acknowledged as one possible missing link relevant to the development of a social theory of HCI (Nardi 1995).

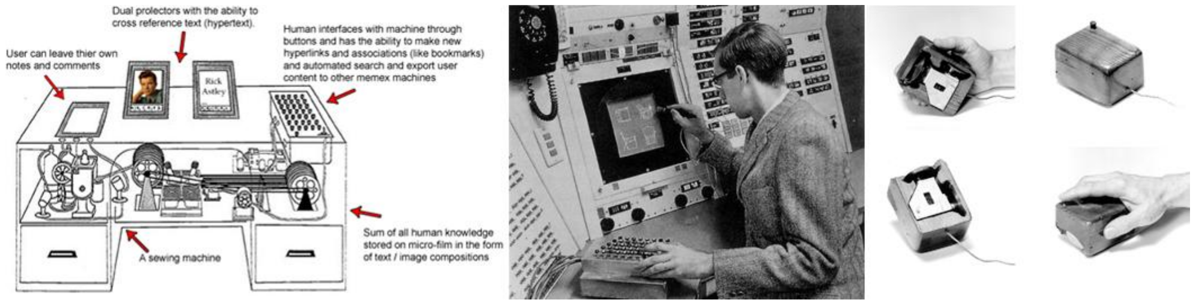

Figure 10: Vannevar Bush's Memex; Ivan Sutherland's Sketchpad; Douglas Englebart's Mouse

2.2 INTERACTIVITY: CONSTRUCTIONISM

Seymour Papert, founder of the MIT Media Lab worked with Paiget between 1958 and 1963 and collaborated with Minsky at MIT.[6] He was a key figure in the development of the *LOGO*[7] turtle (Figure 11) in 1967, *LOGO*, a custom made software system, allowed its users to drive an electronic turtle that generated complex patterns through repeated iterations. It aimed to facilitate knowledge construction processes of children allowing them to solve simple mathematical and geometric problems in an environment of play through their interaction almost without their realization. Papert later developed a learning paradigm called *constructionism* drawing from Paiget's ideas of *constructivism*. However similar in sound and origin, the distinctions between the two are significant. Whilst Paiget's *constructivism* facilitates understanding of a child's

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6 Co-authors of *Perceptrons*, on neural networks and artificial intelligence

7 *LOGO* was developed with Daniel Bobrow, Wally Feurzeig, and Cynthia Solomon

developmental stages describing knowledge acquisition processes, Papert's *constructionism* privileges learning through the knowledge constructions one makes in the tangible world as an active learning tool, each one individual, singular and unique according to its context. *Constructionism* is therefore a precursor to experiential learning and problem based learning. Papert, although careful to avoid a singular definition of *constructionism* defined it thus: "From constructivist theories of psychology we take a view of learning as a reconstruction rather than as a transmission of knowledge. Then we extend the idea of manipulative materials to the idea that learning is most effective when part of an activity the learner experiences as constructing is a meaningful product" (Sabelli 2008, p78).

Figure 11: Seymour Papert: Logo Turtle and Lego Mindstorms

Papert developed the principles of constructionism into a computer based mathematics learning tool called *Microworlds* in which learning is a natural process formed by the learner's interaction with computers to create that learner's constructed *microworld*.[8] As Papert outlines: "We'd like the computer to become an invisible part of things that learners do. We'd like mathematics to become an invisible part of things that people do, and then only later, when it's been intuitively understood, when it's part of your unconscious mind, then it's time to be formal, and have formal classes, and teach mathematics as an abstract formal subject" (Papert 1980, p17). Contrasting the episteme of *constructionism* with the technocratic *instructionism* or the "pipeline" mode of learning is thus a fundamental division between the nature of knowing and the nature of knowledge. These represent two distinct poles not only in education but which are in fact philosophical differences that go the heart of knowledge as relative or knowledge as truth, reflecting the intrinsic value systems that society or culture has. Papert's approach indicates a significant paradigm shift: "The presence of computers begins to go beyond first impact when it alters the nature of the learning process; for example, if it shifts the balance between transfer of knowledge to students …. and the production of knowledge by students. It will have really gone beyond it if computers play a part in mediating a change in the criteria that govern what kinds of knowledge are valued in education" (Papert & Idit, 1991, p23). If *constructionism* generates a myriad of individual learning experiences (*microworlds*) each singular and unique, then the relativistic model for the sum of knowledge generated in such learning environments will be radically different from the monistic model that has broadly prevailed in education. In essence this is closer to the teaching and learning models of many design schools today.

In an education context, computer interaction has been dominated by software driven approaches. In recent years this has shifted towards programmable tangible and physical computing interaction.

8 These concepts are elaborated by Papert in *Mindstorms: Children, Computers, and Powerful Ideas* (1980), later developed into the *Lego Mindstorms* with the MIT Media Lab.

Recent changes to the UK National Curriculum (Department of Education 2013) integrating computer learning has helped facilitate the proliferation of Raspberry Pi and allow access of these technologies to new schoolchildren user groups. This is paralleled by initiatives that contemporize Papert's *microworlds* approaches, evident in Mitch Resnick's Lifelong Kindergarten approach and the development of the Pico Cricket Kits and Scratch programming environments aimed at facilitating children's learning processes towards the creative society (perhaps a second order *constructionism*).

3. CONCLUSION

Characteristic of all these approaches is a simplification and facilitation of learning processes. Additionally, the *human action cycle* (Norman, 1988) although usually considered in the context of human computer interaction is useful when applied to the learning context of physical computing. Norman's user interface design principles which include affordance, feedback, visibility and tolerance are structured as a cycle that includes both physical and cognitive activities and the interrelations of both of these. Key to this is the nature of feedback and transition between the different parts of this system. Lack of clear feedback results in a dysfunctional HCI, and this is equally true of earlier experiments such as Papert's *Mindstorm* or *LOGO* systems. The nature of knowledge acquisition within this depends on a relatively smooth flow of action, feedback and response by the learner and this may be dependent on the existence of otherwise of optimal paths or channels for this process to occur.9 As in any cybernetic system, the nature of conversation or information exchange, feedback and response is intrinsic to the nature of the system. This requires at base a degree of common or intuitive language, such that the shifting in mid conversation of a low level language to a higher order one (as easily happens in physical computing) can easily disrupt (in a novice) the feedback process and by implication the construction of knowledge or learning processes.

Whilst my interactive teaching and learning work presented here is a small contribution to the principles of *constructionism*, its role in critically questioning the nature of interactive learning tangentially indicates opportunities to develop these principles further. Additionally, removing technical barriers to facilitate the learning experience clearly has wider implications and applications; the author is currently looking at interactive and technology teaching in secondary and primary education in Hong Kong in order to test this process further. The approach can help to make access to this field easier and faster for students and designers.

"I hear and I forget. I see and I remember. I do and I understand" (Confucius)

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9 The "Optimal experience" concept as part of Mihaly Csikszentmihalyi's Flow Theory may be of relevance here

REFERENCES:

Brand, S., *Whole Earth Catalogue,* The Portola Institute, Menlo Park CA., 1971.

Brennan, K., Chung, M., & Hawson, J., "Creative computing - a design-based introduction to computational thinking," *Nature*, 2011.

Bringuier, J., Conversations with Piaget, Chicago University Press, Chicago, 1980.

Dessauce, M., *The Inflatable Moment: Pneumatics and Protest in '68*, Princeton Architectural Press, NY, 1999.

Department of Education, "Computing programmes of study: key stages 1 and 2. National curriculum in England," UK Government, UK, 2013

Dourish, P., Where the Action Is: The Foundations of Embodied Interaction, MIT Press, Cambridge MA, 2004

Drescher, G., Made-Up Minds: A Constructivist Approach to Artificial Intelligence, MIT Press, Boston, 1991.

Jacko, J.,A., *Human-Computer Interaction: Design and Development Approaches: 14th International Conference HCI International*, Springer, NY, 2011,

Klemmer S.R., Verplank, B., Ju, W., "Teaching Embodied Interaction Design Practice," *Journal of Computing Sciences in Colleges* 25, 2010

Ha, L., & Lincoln J., "Interactivity Reexamined: A Baseline Analysis of Early Business Web Sites," *Journal of Broadcasting & Electronic Media*, 42 (4), 457-474, 1998.

Hasdell, P., "Artificial Ecologies: Second Nature, Emergent Phenomena" in *Wild Nature and the Digital Life issue of the Leonardo Electronic Almanac*, ed. S. Thomas and D. Grigar, MIT publishers, Boston, 2006.

Huizinga, J., Homo Ludens: A Study of the Play Element in Culture, Beacon Press, Boston, 1955.

Igoe, T., & O'Sullivan, D., *Physical Computing: Sensing and Controlling the Physical World with Computers*. Premier Press, NY, 2004.

McCullough, M., *Digital Ground - Architecture, Pervasive Computing, and Environmental Knowing*, MIT Press, Cambridge, MA, 2004.

Minsky, M., and Papert, S., Perceptrons, An Introduction to Computational Geometry, MIT Press, Cambridge MA, 1969.

Nardi, B., Context and Consciousness: Activity Theory and Human-Computer Interaction, MIT Press, Cambridge MA, 1995.

Papert, S., *Mindstorms: Children, Computers, and Powerful Ideas*, Basic Books, NY, 1980.

Papert, S., From a video conference presentation to educators in Japan, 1980, referenced http://www.papert.org/articles/const_inst/const_inst2.html accessed 30-9-2014.

Papert, S. and Harel, I., *Constructionism* Ablex Publishing Corporation, NY, 1991.

Piaget, J., "Play, Dreams and Imitation" in *Childhood*, Norton Books, NY, 1962.

Piaget, J., *The psychology of the child*, New York: Basic Books, NY 1972.

Resnick, M., "Sowing the Seeds for a More Creative Society," International Society for Technology in Education, 2007.

Sabelli, N., "Constructionism: A New Opportunity for Elementary Science Education," *DRL Division of Research on Learning in Formal and Informal Settings*, 193-206, 2008.