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TOOLS FOR CONSTRUCTIVE LEARNING: RETHINKING INTERACTIVITY

Edith Ackermann
Edith@media.mit.edu

"A clearer conception of the processes involved in direct experience will permit us to better examine the nature and extent to which mediated experience enrich, complement, and substitute for that direct experience". Olson, D. and Bruner J.

Introduction

It is nowadays accepted that direct experience or "hands-on" activities are essential to learning. An increasing number of software designers, cognitive scientists and educators have come to the view that experience is actively constructed and reconstructed through direct interaction with the world, and that, indeed, knowledge *is* experience. According to this view, a learner is not an empty vessel to be filled, or a passive listener to be filled-in. Knowledge is not a mere commodity to be transmitted from one person to another. It is not an entity to be emitted at one end, encoded, stored, retrieved, and reapplied at the other. The conduit metaphor is progressively fading away, and being replaced by the more recent toolmaker paradigm (Reddy, 1979). Children are perceived as the active builders of their own cognitive tools, comprising both mental capacities and external mediations that prolong those mental capacities. Constructivism is in the air, and, especially among educational software designers, interactivity has become the "buzzword".

No doubt, interactivity is essential to learning. However, this should not lead us to consider that "hands-on" activities alone will make for meaningful experience or constructive learning. A great deal of rather contrived interactive games, educational software, and curricular materials, have invaded school and home under the umbrella term "Interactive Tools for Constructive Learning." At the same time, too many "interactivists" regard activities such as reading a text, viewing a film or listening to a story as being passive, when in fact they require a great deal of active reconstruction (Bordwell, 1985; Iser, 1978). I find it useful to think of reading a book as a conversation with the printed material, and of the reader as a playwright who mentally recasts the plot through the lens of her own experience (Ackermann, 1993). Obviously, recasting a plot in one's head is not the same as reproducing it in some external form. My purpose in this presentation is to rethink interactivity and to propose a series of criteria, or leverage points which may, hopefully, be useful in the design and evaluation of interactive learning environments.

Different people engage in varying ways with their social, physical and mental world. Their beliefs about how they impact the world or are driven by it, varies too. Moreover, a given person may approach a situation differently according to time and place. For example, people may want to take initiative or be guided, to immerse themselves or operate at a distance, to project ideas and feelings outwards (giving them form) or incorporate the feelings and ideas of others. To know is to relate, one could say. And to relate is to keep an ongoing balance between getting embedded and emerging from embedded-ness (Kegan, 1982). To relate is to control boundaries, to regulate exchanges and, by so doing, to constantly reconfigure both outer and inner worlds.

Man-made environments "afford" different degrees of freedom or guidance, and provide more or less space for exploring, expressing, and communicating ideas. Some environments allow you to dive-in into them (e.g. Virtual Reality technology), while others keep you operating at a distance (e.g. small-scale construction kits such as LEGO, games such as TETRIS, Nintendo). Some may take you for a ride (Omnimax) while others urge you into the driver's seat (Cosmic Osmo, Spelunx). Some environments let you keep track of your explorations, re-edit and reorganize these traces, while others don't. Some are almost infinitely reconfigurable, taking on whatever shape you give them (sandboxes, tinker toys, or "MUDs"[1]), while others are highly constrained, and keep their identity. They won't let you alter their structure (e.g. nesting Russian dolls, multiple choice questionnaires). It is worthwhile noting that through interaction with a highly malleable environment, users generally end up with constructions that evoke or mirror their own activity. Poking un-malleable environments, in contrast, is more likely to lead subjects to reconstructing "its logic" or structure.

The type of control or initiative taken by a learner, as well as the nature of the feedback provided, also determine the nature of a learning experience. It does not feel the same to immerse oneself in an environment like a scuba diver, or to manipulate it at a distance like a conductor. It is not the same to interact in "real time," or to mediate an interaction through symbol use.

In the following sections, I describe the processes involved in direct experience, and contrast them with those involved in mediated experience. This comparison of direct and mediated experience should permit us to enrich our ideas about interactivity and, thus, to formulate a few leverage points useful for designing and evaluating interactive environments.

1. Unpacking "interactivity"

As mentioned above, interactivity as such is no guarantee for constructive learning. Instead, it is the type of control, as well as the nature of the feedback provided that make for a richer, or less engaging, learning experience. These qualities vary enormously from one interactive setting to the next. Different people, at different times and places, may favor one or the other.

In this section, I argue that:

- "Hands-on" is not enough without "heads-in" and "play-back,"
- Personal experience is not just direct manipulation of real objects, and
- Concrete is not equivalent to physical.

• "Hands-on" won't do without "heads-in"

[1] MUD stands for Multi-User Dungeon. The term is generic and refers to a variety of multi-user game environments (MUSEs, MUSHs, MOOs). In all these games players can create their identities and/or habitats, and share them with other players, currently logged in (Bruckman, A., 1993).

Any activity remains essentially undirected and non-controllable, blind and meaningless, if it is just acted out without a re-evaluation of its consequences. People constantly reconsider their acts in the light of what has been done previously, and of what the action was supposed to achieve. In thinking about learning, the smallest unit to be considered should not be *action* but *circular reaction*. The term was introduced by Baldwin and has been used by Piaget. It refers to a psychological primitive made of an action (triggered under certain circumstances), plus an evaluation function, which, in turn, calls for the pursuit, discontinuation, or modification of this action depending on its perceived consequences. The biggest breakthrough in a child's development is not the ability to act per se, but rather, to inhibit, transform, or defer action, whenever its consequences are perceived as unsatisfactory. The basic law of the effect is of disconcerting simplicity: *if good, then do it again. If no good, then stop, replace by other, or defer*.

Psychologists and pedagogues generally agree that reliable feedback is what enables learning. Yet, little consensus exists, to this day, as to what *kind* of feedback is most appropriate and *at what moment* in a learner's activity feedback should be given. Is it better to tell right from wrong, to give out solutions, or to propose simpler tasks? Is it more useful to intervene as soon as an "error" occurs, or at the end of an episode? Some think that external reinforcement or sanctions are needed, while others claim that intrinsic motivation is more important. Little agreement has been reached, especially in multi-cultural communities, as to *who is entitled—and in the name of what*—to decide *what and how* someone else ought to learn.

One of the most difficult questions, for both pedagogues and educational software designers, be they constructivists or not, is to determine how much to tell and how much to leave implicit, if you want a learner to make sense of a situation for themselves. For software designers, the same question becomes: How much knowledge—or intelligence—should be built into a system, and how much should be left for the user to discover? What are the building blocks, or primitives, that a user should be messing around with to reach deeper understanding in a given task? What is an optimal level of granularity, and how much flexibility should the user have to open and close "black boxes?"

Intuitively, we all know that if an instructor, a system, or a narrator for that matter, tells us too much, we will eventually lose interest. All the intrigues fall flat, all the slots are filled, no interpretive tension is left. On the other hand, if a narrator does not reveal enough, or gives inconsistent signals, the plot gets confusing and explorations may wonder endlessly. It is only within a fairly narrow area, which I call the "zone of optimal assimilation and accommodation," that creative reconstruction can take place. Outside of this area, either through boredom or incomprehension, people cease to wonder and loose interest.

• Personal experience is not just direct manipulation of real objects. Concrete is not just physical.

The objects we interact with are not merely physical. They may be other people with their own intentions and goals. They may also be our own activity, previously encapsulated and turned into tangible objects to operate upon. People give form to their ideas by exteriorizing them, and, once built, these forms become the “mediational means” through which people shape, express and exchange ideas. Moreover, any previous activity, as well any object in the world can be replaced by a token that stands for it, or an "ersatz" that replaces it in its absence. By the age of two, children learn to de-couple an action from its usually associated props. Later, they learn to encapsulate a previous activity as an object-to-think with. This leads us to the next section which deals with the potentials of mediated experience, in particular a the role of symbolic play and pretense in learning.

2. Exploring the potential of mediated experience.

I have argued that "hands-on" activities without "heads-in" is insufficient. I would like to add here that "hands-on plus heads-in" remains also limited if it is not accompanied by the ability to "play-back", or recast an event, either in one's head or better, on some external symbolic substrate. People not only construct and reconstruct their world and selves through direct interaction, but they also describe and redescribe what happens to them. People like to tell and listen to stories. From age two on, young children learn to reenact their experience in a variety of ways and for a variety of purposes, such as modeling and communicating. They become increasingly better at adjusting their stories to a specific interlocutor's willingness or ability to understand, or being empathic.

In this section, I argue that:

- "Play-back," or the ability to recast ones experience in a make-believe world plays a key role in interactive learning,
- The realer is not always the better.

The ability to evoke or reenact an event in its absence constitutes a major turning point in children's development. It enables them to break loose from the here-and-now contingencies, which are characteristic of sensori-motor activities, and to introduce ever greater distances between an action and its outcome. The child becomes able to keep hold of a goal while embarked in some tortuous detour meant to reach it. She can re-engage in activities that have been interrupted, and keep track of past experience as a way of anticipating the future.

• "Play-Back": Doing As-if / Asking What-if

Toddlers naturally engage in what Piaget calls "differed imitation" (Piaget, 1962). Differed imitation refers to the ability to reproduce a complex pattern of actions in absence of the model. Its apparition opens the door to other manifestations of the symbolic function, such as pretense play, monologues, and other forms of verbal reenactments with real and imaginary companions.

In a detailed study of his own children, Piaget describes the case of Jacqueline (1;4) who all of the sudden grabs her pillow, folds it in her right hand, sucks her thumb, lays down on her side, and says, smiling: "nono" (meaning: "*I am sleeping*"). Two days later, Jacqueline goes through the exact same moves, using different objects, such as a bear, a plush dog, mom's sweater. This ability to recast an episode at a later moment allows Jacqueline to incorporate a great deal of information about the original scene. More important, it allows her to generate variations upon the original scene. She learns how to de-couple the real from the replayed episode and her own action from its usually associated props. Moving from one to the other conveys a sense of irony, a joke-like feeling.

Another classical example of early pretense, by Leslie (Leslie, 1988), goes as follows: A child takes a banana, puts it close to her ear as if it were a telephone, and calls up her mom. Mother looks at the child, smiles, puts her right hand to her ear and, with a slightly playful voice, answers: "hello" as-if she, indeed, thought the banana was a phone. The most striking feature about pretense play is that the child is perfectly aware of the make-believe character of the performed act. If mother were to declare: "this is a phone" while pointing to a pencil, the child would by no means take the statement, nor be confused. The pencil, in the child's eye, *is not* a telephone. It is *meant to be* a telephone. Children negotiate pretense in extremely sophisticated ways. They know how to emit and read clues indicating at what level of "reality" a given interaction is taking place.

These "*mises en scene*" I suggest, are the very laboratories in which "real" learning takes place. Acting out in make-believe worlds provides an elaboration space in which learners can explore ideas and take risks without having to endure the unpleasant consequences of an act that would be carried out in unsafe terrain.

• The realer is not always the better

It is through pretense [or fantasy] play that young and old can work out some intriguing aspects of their environment and personal [affective and cognitive] experience. In Piaget's words, play allows one to bend reality, and thus, liberates assimilation: "It is indispensable to a child's affective and intellectual equilibrium that he has available to him an area of activity whose motivation is not adaptation to reality but, on the contrary, assimilation of reality to the self, without constraints and sanctions. Such an area is play" (Piaget, 1962, p. 58). For Winnicott, play provides a *transitional zone*, between world and self, in which people can explore in a proactive, yet safe, manner (Winnicott, 1989). Linus' blanket or a child's imaginary companion are precious not because they are real, but because they are resilient: they can be cherished, hated, mutilated, re-appropriated without much resistance. They survive the child's aggression and still remain available. They allow for real exploration in a make-believe version of a child's reality. In a similar way, Bettelheim describes fairy tales as particularly rich microcosms to work out identity issues. The materials provided in a fairy tale are evocative of a person's psychological and emotional struggles, which growing up entails. They can be addressed and thought through safely. In Bettelheim's words: "When unconscious materials are to some degree permitted to come to awareness and worked through imagination (domesticated and played out on a substitute), its potential for causing harm, to oneself and to others is much reduced" (Bettelheim, 1977, p. 7). Sherry Turkle, in a recent paper, discusses the impact of computer games, such as Nintendo and MUDs (Turkle, 1991). Not unlike fairy tales, these games enable users to play around with identity issues, yet through actively controlling a computer-based microworlds (Papert, 1993). It is not the same, obviously, to identify with a character in a fairy tale by mentally following him through his torments and joys, and to actively engage in the conquest of some frightening, yet safe, habitat filled with monsters and allies. The mental engagement may be similar. Yet, in one case, the child reconstructs the drama from the viewpoint of a back seat driver, while in the other, she becomes the actual driver, having to make decisions and choices as she navigates along.

What does all this have to do with learning?

My claim is that not merely play, but any other exploratory process requires a learner's ability to establish a dialogue between what could be and what is, between the potential and the actual. The scientific method itself can be viewed as such a dialogue between fact and fancy, between what could be true and what is in fact the case. Scientific inquiry, as much as other forms of cognitive investigation, indeed, require playing "what if." And "playing what if" will no doubt happen more effectively if an idea, or hypothesis, can be run "for good" onto some external support, or medium. Children as well as adults are usually extremely good at selecting/creating the tools and props best suited to "run" important ideas. They constantly seek out, regroup and reconfigure those very objects-in-the-world that best allow them to explore some currently relevant set of questionings. People are the natural designers of their own learning environments. They are "microworlding," one could say, creating their own characters and casts, putting them in motion, and making them interact dynamically. They attribute different "masks" or feature to each character. They take on a given character's viewpoint (what-if I were another), and they switch roles. Dynamic modeling, or "microworlding," is a necessary condition for constructive learning. Without giving form or expression to ones' ideas, by projecting them out [making them

tangible], no exploration can be carried out very far. And without giving "life" to these forms, projected ideas may remain cast in stone. To conclude, interactivity is important, not because it allows the direct manipulation of real objects, but because it fosters the construction of models or artifacts, in which an intriguing idea (thought and feeling) can be run or played out "for good" in a make-believe world.

3. Assessing Interactive Environments

Designers, researchers and educators need a vocabulary to assess the qualities of interactive environments in terms of the mental "elbow room" they provide. In this section, I outline a conceptual framework that helped a few colleagues and me gain insight upon the many claims made on behalf of interactive media, and in particular virtual technologies for learning, or Virtual Reality.

Why Virtual Reality?

Virtual Reality offers an unusual blend of direct and mediated experience, of reality and fancy, which makes it a good example for discussion. A Virtual Reality is a computational environment that allows one or many users to immerse themselves and to navigate interactively via some sensory apparatus (visual display, force feedback, headphone display). In a broader sense, aVirtual Reality could be any kind of habitat, or microworld, in which one or many users can play-out some imagined scenario onto a tangible and responsive support. A Virtual Reality can be a simulation of an existing, yet inaccessible, place, such as the interior of a cell, or an imaginary location. It can be a deserted landscape, responding actively to a user's solicitation, or an area populated with other users, currently logged-in, who communicate among themselves (MUDs). Note that in entering a MUD, each user composes her own character and launches it into the shared habitat (Bruckman, 1993). Virtual habitats are more or less reconfigurable, and the types of operations afforded vary.

Virtual Reality is a work in progress and the methodologies for designing and evaluating it are still in the exploratory phase. In a recent tutorial given at InterCHI '93, Marc Davis, Kevin McGee and I decided to launch a few criteria, that we could then use as generative engines for exploring the parameters and affordances of particular cases of virtual phenomena. Such a working vocabulary has helped us imagine richer versions of existing Virtual Realities, not solely from a "technical" perspective, but also from a psychological point of view based on our everyday experience with objects, symbols, and other people.[2]

In this section, I touch upon five different **leverage points,** and develop one in more detail: transformation. For each leverage point I formulate a series of questions that may provide a useful lens for assessing VR, as well as other interactive environments. I close with a few comments on each leverage point.

-Transformation. To what extent does an activity transform the object and the agent of this activity? What object is being transformed? Is this object internal or external? Is it a thing, a process, or a representation? Does an activity leave a trace in the world? Can these traces be conserved, manipulated? How far does a transformation propagate? What kinds of transformations does an object afford?

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[2]. The ideas presented in the following section have been elaborated in conjunction with Marc Davis and Kevin Mc Gee, for a tutorial given at InterCHI'93 in Amsterdam. A more extensive description of the leverage points can be found in (Ackermann, Davis, Mc Gee, 1993, pp 13-73)

- Immersion/Point of View. What is our relationship to the field of activity? Are we totally immersed in our world, or is the world an object that we can stand outside of? Can we move back and forth between being embedded and emerging from embedded-ness? Is there any advantage in moving back and forth? What is our stance in the world? Do we look out at the world from our own viewpoint (first person), look at ourselves as another (third person), or look at another as ourselves (second person)? Are we able to alternate from one perspective to another? What do we gain by doing so?

- Verisimilitude. Is the make-believe world we operate upon realistic? Is greater realism always better? Or does the ability to model imaginary scenarios—things that could *never* exist in the physical world—, help us gain deeper understanding of phenomena?

- Perceptual/Symbolic Modalities. Which senses are engaged in our experience? To what extent can one sensory modality enrich or neutralize the others? In which medium or modality do we carry out a symbolic manipulation? What are the trade-offs in using one or the other?

- Locus of Control. Who is in charge? Who is the agent of a transformation? Is it me or not me? Is the agent singular or multiple? What agents am I made of? Am I extended, prosthetized through distributing my activity and identity across multiple agents and processes? Do I project out little parts of myself into my object of inquiry? To what extent do I "become this object or does it become me"?

Why transformation?

The richness of a Virtual Reality comes from its potential to give us greater control not just over the objects we transform, but over the properties of transformations themselves. Transformations become accessible to us if they are tangible or object-like. To become tangible, transformations need to be "recorded," and "recordings" must be left behind as a workable trace. Transformations can be "recorded" in the object itself, which thereby carries the trace of its own history, just as the mountainside bears the history of erosion over millennia. Transformations can also be "recorded" in some other medium, like a film or a computer simulation which can be replayed and altered) "Recording" refers to any process by which we give *form* to an action or thought. Being able to reconfigure, or re-edit, these forms is essential to learning. Virtual Reality allows us to play with the properties of transformations in ways not possible in the physical world.

We have identified four properties of transformation, which enable us to think about the design and evaluation of VR in terms of the experiences they afford.

• Durability refers to the extent to which a transformation survives. The invention of writing, for example, can be thought of as a mean to "freeze" and conserve the ephemeral acts of oral communication.

• Accessibility addresses the rules and conventions which allow transformation of the object. A useful example to think about accessibility is a computer file system. A file can be readable and writeable by the authorized user, but not writeable by others. It may not even be readable to people lacking certain permissions. Through the intricate intertwining of permissions and conventions, we make transformations accessible to ourselves and to others. In our everyday social interactions, we have constructed zones of varying access—a topography of accessibility—which VR technology could actually transform. We see the beginnings of this in virtual communities on the Internet and on the increasing number of public access computer networks. In these virtual environments, our identity can be bracketed and reframed in ways which are not possible in our physical and social existence. Just as in a carnival, our created persona offers new access to others (e.g. gender swapping).

•Propagation refers to the effects of a transformation on the environment in which it takes place. A simple way to conceptualize propagation is to think of what happens to the surface of a pond if we drop a pebble in it. The ripples propagate outwards to create a global circular pattern. Another example of propagation is the domino effect in which the fall of one domino causes all the others to fall as well. Limiting propagation can be essential to the functioning of a system. The introduction of modularity allows many systems, from complex computer programs to social groups, to function smoothly. Limiting propagation helps people live and work together without functioning always as one single corpus.

• Transformability is the self-recursive step—the ability to apply transformations to transformations themselves. One of the unique properties of Virtual Realities is that they allow us to transform transformations in ways not possible in the physical world. For example, Virtual Reality affords the possibility of actually *reversing* a transformation. In the physical world, many transformations are irreversible: aging, burning love letters, digesting chocolate, and breaking mirrors. In Virtual Reality the effects of any transformation can potentially be "undone". Designers are often faced with the tension between letting individuals "undo" their transformations and the computational expense of maintaining enough state information to make this possible. Psychologists, on the other hand, insist that users should always be able to "undo" their own "doing," and to come back to a previous state, if needed.

To close this section, I briefly outline the function of the other leverage points:

• **Immersion** *per se* does not make for meaningful experience. As Kegan points out in the *Evolving Self,* people learn little from their experience as long as they are totally immersed in it. There comes a time when they remove themselves and contemplate what they have done from a distance. They encapsulate their experience by giving it a form, and this form, once built, gains a life of its own, and can be addressed as if it were "not me". From then on, a new cycle can begin, because as soon as the dialogue gets started between "me" and "my artifact", the stage is set for new and deeper connectedness and understanding. It is the alternation, between embedded-ness and emergence from embedded-ness, which punctuates people's interactions with the world and determines their way of knowing and growing.

•**Points of view** need to change constantly. It is through contrasting our own perspective with those of others, putting ourselves in other people's "shoes", that we enrich our understanding of the world and ourselves. Playing "what if I were another," or switching roles is, indeed, essential to learning.

• **Verisimilitude.** VR worlds are potentially rich not because of their resemblance to the real world, but because they allow us to construct our own realities, and to make them tangible, explore-able, and shareable.

• **Locus of control**. Becoming-one with a phenomenon, by throwing ourselves into the object focused, may lead to a momentary sense of loss (drifting away from oneself) but allows for change and innovation. Imposing one's order upon the world may lead to momentary closure, but allows one to maintain an internal equilibrium. Any adapted behavior comes as a result of maintaining a balance between stability and change, tradition and innovation.

People set or blur boundaries, take over control or let go of it, as a way to "maintain the maximum of the acquired, while discovering the maximum of novelty".

4. Conclusions

In this paper, I have unpacked the notion of interactivity, showing that "hands-on" activities remain essentially blind and undirected without our ability to put our "heads in." "Heads-in," in turn, requires that we evaluate what we have done so far in the light of what we wanted to achieve, and that we monitor our activity accordingly. I further argue that "hand-on with heads-in" also remains limited without the additional possibility to recast our experience in a make-believe word. These reenactments, which I call "play-back," enable learners to decouple an action from its usually associated context and props, and to experiment with its consequences under safe conditions. Pretense play (or doing as-if) I claim, is an extremely serious component of "real" learning. It opens elaboration spaces where young and old can work out some intriguing aspects of their environment and personal [affective and cognitive] experience. Any type of inquiry, scientific or not, presupposes that a learner establishes a dialogue between fact and fancy, between the actual and the possible. Doing as if and playing what-if are the mechanisms by which we get such a dialogue going.

Examining the processes involved in direct and mediated experience has allowed me to bring to the fore some of the principles which govern [inter]active learning. I have shown, in particular, 1) that personal experience is not just direct manipulation of real objects; 2) that concrete is not equivalent to physical; and 3) that the realer is not always the better. It is the type of control or initiative taken by a learner, as well as the nature of the feedback provided, which make for a richer, or less engaging, learning experience.

Lastly, I have formulated a few leverage points, to help designers, teachers and users explore the qualities of interactive environments in terms of the kinds of experience they afford. I have limited my discussion to the case of Virtual Reality, because Virtual Reality provides a unique blend of direct and mediated experience, of reality and fancy. Leverage points include the degree to which a user can reconfigure the world, keep track of her transformations, and re-edit them ; the nature and properties of the transformations; the user's immersion and point of view in an environment; the sensory and symbolic modalities of interaction; the locus of control. These leverage points are a starting point. They have helped us, and will hopefully help others, to explore the affordances of particular cases of interactive environments, not solely from a technical perspective, but from our own accumulated knowledge of everyday encounters with objects, symbols, and other people. And since virtual phenomena have been with us for a long time, we generally know more than we first thought about their potentials and limitations.

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