



## **Situations, interaction, process and affordances: An ecological psychology perspective**

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**Abstract.** From an ecological psychology perspective, a full analysis of any learning context must acknowledge the complex nonlinear dynamics that unfold as an intentionally-driven learner interacts with a technology-based purposefully designed learning environment. Further, a full analysis must avoid focusing only on the individual within the learning context and not accounting for the intentionality and constraining influence of the designer and the broader community. Finally, such an analysis must either pin down how learning and development can be driven by perception of the environment alone (detection of affordances), or alternatively from an ecological perspective, by a cyclical interaction of perception *and* action. This paper presents these parameters for any model of context or situation in relationship to the issues raised by Akhras and Self's (this issue) presentation on intelligent learning environments. We propose that a full situation model would need to incorporate constraints not only from the environment, but also from the individual and most precisely from the specific interaction at the moment of an occasion.

**Keywords:** affordances, constructivism, context, ecological psychology, intelligent tutoring systems, situated cognition

### **An ecological psychology perspective on situations, interactions, process and affordances**

Akhras and Self (this issue) developed a description of the general design for Intelligent Learning Environments (ILE) and contrasted it with the design of Intelligent Tutoring Systems (ITSs). ITSs are characterized as being based on an objectivist epistemology while ILEs are based on constructivist and situated cognition epistemology. Their goal is to model the domain of information to be learned in terms of situation<sup>1</sup> types and situation models, to focus on interactions as a process, and to formalize a description of the "affordances of situations" (e.g., pp. 6 and 15).

This work provoked two substantive discussions within our group concerning the role of intentionality in thinking and learning, and concerning

the formal specification of “situations” and “context.” Both of these issues have broad implications for the constructivist epistemology and pedagogy discussed. While we would be the first to agree that no one has yet fully described a theory of context, in this commentary we hope to contribute to this worthwhile endeavor. We hope to convey some of the elements we believe to be essential when taking an ecological psychology approach to describing situations, interactions, process and affordances. Specifically first, we assert that intentionality is central to an understanding of situations and involves its own set of dynamics that must be modeled. Second, we assert that affordances are codetermined by properties of learners and as such must be described as dual.

A full analysis of the learning context must acknowledge the complex nonlinear dynamics that unfold as an intentionally-driven learner interacts with a technology-based purposefully designed learning environment. We will outline an approach to viewing the creation of learners’ behaviors as a cascade of constraints, or reductions in degrees of freedom, that are characteristic of ontological descent. We do this to make the case that any model of learner-environment interactions must at least acknowledge the multidimensional nonlinear dynamics that unfold as a particular learner interacts with a particular learning environment on a particular occasion in space-time. Just as the cellular organization of animals may be described in the mathematics of autokatekinetic systems, the intentionality of learners interacting with learning environments may be similarly described (Barab et al., 1999).

From an ecological perspective, some things in the environment are inanimate while others are intentionally-driven, or have agency. This gives rise to an agent-environment interaction. Simple animals like butterflies and termites have simple intentions to eat and reproduce. Other animals show behaviors that evidence more elaborate intentions such as mothering and sounding warning calls. In contrast, the intentionality of humans is made further complex by the ability to represent in language and reason logically. Inanimate objects are subject to a physics-based interaction with their environment. While intentional agents are also bound by the laws of physics, their interaction with the environment is also information-driven. Humans also organize into social structures which enable intentionality to be described at the social or community level as well. That is, we may have individual goals, but we also have shared goals as we work in groups.

Thus, we believe a full analysis must avoid focusing on only the individual within the learning context and not accounting for the intentionality and constraining influence of the designer, the broader community, and a range of ontological constraints. The danger here is positing a version of constructivism that leads to completely idiosyncratic understandings of

the world that have limited functional value in the greater community. For example, most of us would not like to have a surgeon whose understanding of anatomy was completely self-constructed. Instead, that understanding, while individually constructed, must be tested as having concrete functional value as well as consistency within the community of practicing surgeons – the medical community. This functionally and socially defined “truth” must be acknowledged as well as other nested levels of constraints on the ongoing agent-environment interaction which can determine the functional value of understanding, as a replacement for the objectivist’s one objective “truth.”

Finally, such an analysis must either pin down how learning and development can be driven by perception of the environment alone (detection of affordances), or alternatively from an ecological perspective, by a cyclical interaction of perception *and* action. Since Gibson (1979) clearly delineated the concept of affordances as stable properties of the environment, specifically those that specify possibilities for action for a class of agents, and he located these properties in the environment, it raises the issue as to whether the environment alone has implications for learning, or whether the full analysis of context must acknowledge an active role, or “generative learning” effect (e.g., Wittrock, 1990) that acts as the dual of perception to influence learning. It is our assertion that describing affordances is not enough, and a full analysis of context requires an acknowledgement of the action side of perception-action and affordances-effectivities as duals (Shaw, 1987).

### **Ontological descent**

As our first commentary, we would like to highlight the importance of overtly including intentionality in the descriptions of interactions. In describing interactions, Akhras and Self (this issue) model the linear additive nature of interactions and the time scale (defined by command interactions with their ILE system) on which such interactions can be described, assessed, and “reasoned about” (p. 8) by their ILE system. But there is reason to believe that interactions occur at multiple and often simultaneous time scales (Kulikowich & Young, 2001). Thus, a student may be pursuing the goal of becoming a great chef, of being an “A” student in computer class, of being a good wife/daughter/friend, of getting credentials that lead to a career, and of learning salad-making for its own sake all within the context of the authors’ salad-making ILE. This raises issues for the characterization of situation models that presume to connect patterns of interaction in one situation to patterns of interaction in another. In short, such connections may be inherently multi-dimensional and nonlinear, and this could present a consider-

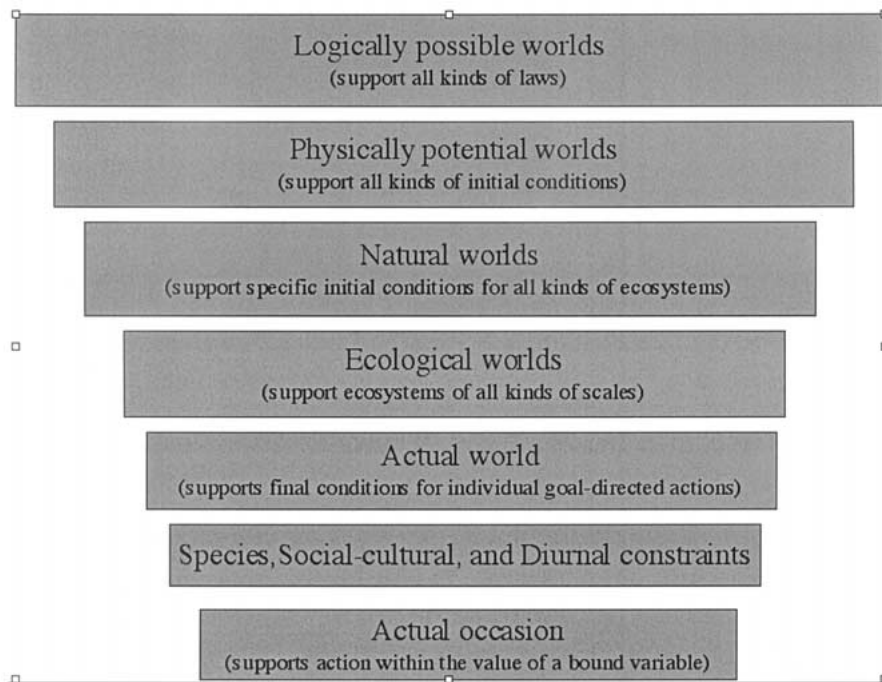


Figure 1. Ontological Descent: Cascading constraints on degrees of freedom.

able challenge when modeling a full description of context, interaction and process.

From an ecological psychology perspective, each learner-environment interaction can be seen as the result of an intentionally-driven agent perceiving and acting on environmental affordances as they move toward their currently adopted goal. Such an ongoing unfolding of behavior has been described in ecological terms as intentional dynamics (Turvey & Shaw, 1995; Young et al., 2000). For present purposes, it is important to highlight the primacy of intentionality to this description, and then pursue the issue of where particular intentions come from.

Research in ecological psychology has recently been applied to an understanding of a variety of topics in coordinated action and perception, including crawlable surfaces (Gibson, 1986), sittable heights (Mark et al., 1990), step-pable heights (Pufall & Dunbar, 1992; Warren, 1984), passable apertures (Warren & Wang, 1987), and time to contact (Kim, Turvey & Carello, 1993). Ecological psychology has also been applied to the broader theory of consciousness (e.g., Greeno, 1994; Shaw & Turvey, 1999; Turvey & Shaw,

1999) and to instructional contexts in engineering and design (e.g., Vicente, 1999).

Figure 1 displays a cascade of constraints that begin with the constraints imposed by logically possible worlds and end, at the bottom, with the moment of a particular occasion, when a particular agent, with a particular goal, takes an action toward that goal in a particular space-time. At each of these levels, the degrees of freedom for behavior are reduced by the constraints imposed by the system at that level.

Recall that mathematically, the concept of degrees of freedom refers to the amount of variability across a set of variables that can be achieved within the constraints of the requisite relationships among the members of a set. Consider a simple algebraic example:

$$x + y + z = 3 \quad (1)$$

Given this,  $x$ ,  $y$ , and  $z$  form a set  $\{x,y,z\}$  of any numbers that add up to 3. There are 2 degrees of freedom in this equation.<sup>2</sup> However, as each variable is assigned a specific value, degrees of freedom are reduced. Given Equation 1 we can assign  $x$  any value, say 4, so now,

$$x = 4 \quad (2)$$

$$4 + y + z = 3 \quad (3)$$

or

$$y + z = -1. \quad (4)$$

We used up a degree of freedom to fix  $x$ . It is also the case we can give  $y$  any value, say  $-2$ . So now,

$$y = -2 \quad (5)$$

$$4 - 2 + z = 3 \quad (6)$$

or

$$z = 1. \quad (7)$$

To fix  $y$  we have used up our second degree of freedom. But now that we have assigned values to  $x$  and  $y$  we are not free to assign an arbitrary value to  $z$  and still have Equation 7 hold true. The variable  $z$  is fully constrained to the value 1. In addition, as in the levels of ontological descent shown in Figure 1, additional relationships among the variables can also use up degrees of freedom.<sup>3</sup>

Consider Equation 1 again. Now, just this equation provides 2 degrees of freedom. Consider the system of Equation 1 again with the additional constraint that  $x = y$  as well:

$$x + y + z = 3 \quad (8)$$

$$x = y \quad (9)$$

Now, this system has only 1 degree of freedom. Similarly, for ontological descent, it is the case that increased numbers of relationships decrease the available degrees of freedom thus constraining behavior.

As in Figure 1, a cascade of constraints can be posited that impose increasing specificity on the agent-environment interaction in a particular learning environment. At the bottom of Figure 1 is a representation of the unfolding goal path that will be taken by a particular agent, with their associated goals and effectivities, on a given occasion, in a particular learning environment, in a particular space-time.

Even once this goal path is undertaken, increased specificity is required to further constrain degrees of freedom as a goal is approached. This additional specificity is provided necessarily by the information field, as described by Kugler et al. (1991):

With each step closer to the goal the information must become ever more specific, thereby tightening the reins on how the action path unfolds, until ultimately, at the moment of accomplishment, the path becomes uniquely defined. The elimination of the degrees of freedom for action control options corresponds to a progressive reduction in the number of paths in the germ from which action paths are selected. Our improving prospects for reaching the goal at some future space-time location are noticeable in the here and now. In this way, the successful action of the perceiving-acting cycle is to distill from all possible paths, in the bifurcation set emerging from the germ, that path that (con)serves the directing intention. (p. 413)

For our purposes, we present this as a more complete description of the nature of situations. Situations emerge as degrees of freedom are gradually squeezed out from all possible actions to only those that meet the constraints of the moment, given the intentions of the learner, the learners particular abilities to act (effectivities) and the affordances of the current environment. Rather than simply being the context in which a pre-supposed goal is acted on, we propose that a full analysis of “situations” must acknowledge the constraints imposed at all these other levels. Thus for us, constructivism does not posit an isolated individual acting alone within the context of a particular learning environment. Rather, the learner is acting within a tightly defined environ-

mental niche whose properties co-determine the nature of the interaction that unfolds. Therefore we would propose that a full situation model would need to incorporate constraints from the environment, but also from the individual and most precisely from the specific interaction at the moment of an occasion.

We assume that learners are, indeed, intentionally-driven systems, having goals and intentions that themselves emerge from an interaction between agent and environment. But as complex systems, they can be driven to pursue multiple intentions simultaneously. So, there are also “dynamics of intentions” (Kugler et al., 1992; Lemke, 2000). That is, each learner has goals that change in priority as they interact with their environment. Then, once a particular goal takes priority, there are the additional dynamics that unfold as the learner acts to move toward that goal – as the action path unfolds. These are the intentional dynamics that are best understood by ecological psychology (e.g., Turvey & Shaw, 1995). So we have both the dynamics of intentions (changing goals) and intentional dynamics (the playing out of the perceiving-acting cycle as a learner works toward any particular goal). It is this set of dynamics, not simply internal states or external rewards, that best capture the coupled interactions continually unfolding between person and environment. We suggest that the dynamics of intentions (changing goals) must be a part of any situation model because they provide an opportunity for new goals to be introduced (by teachers or engaging environments), a process that is fundamental to an ecological psychology version of instruction (Barab et al., 1998).

As the perceiving-acting cycle unfolds over time, the intentions of the agent lead it toward a goal. But we must distinguish the complexity of even this basic statement, since it is by no means linear or unitary. First, the goal or “end state” of the system is more accurately described as a region within the state space, allowing for multiple correct answers (paths) that satisfy the goal constraints (see Shaw & Kinsella-Shaw, 1988, for a detailed description of the  $\Omega$ -cell, a mathematical description of the border constraints imposed by goal adoption). Also, there is rarely one “correct” path or trajectory of interest, and this is more accurately described as a collection of tendencies from among a distribution of paths. This leads us to suggest that any situation model cannot be based on a static objective description of either the student or the learning environments, but rather must be about dynamically modeling the interaction.

As a final note, varied operational definitions of terms like “situation” and “context” have the potential to cause conceptual misunderstandings across discussions of theories of constructivism. In this instance, we should point out that our definition of situation is at variance with that of Akhras and Self (this issue). For us, the learner and the environment together create a

“situation” as a result of ontological descent. For us, the properties of the learner (effectivities) and the properties of the environment as specified in the information field (affordances) combine to form a “situation” whose unit of analysis would most appropriately be the interaction that unfolds (Kulikowich & Young, in press; Young, Kulikowich & Barab 1997). While learners contribute “individual cognitions” (p. 12) and “learner cognitive states” (e.g., Akhras & Self’s Figure 3), for Akhras and Self (this issue) learners are not considered part of the situation. So in their analysis the “environment” seems isomorphic with the “situation,” rather than the situation emerging from an agent-environment interaction.

*Affordances and effectivities: The co-determined nature of ecological psychology*

As our second commentary, we would like to assert that affordances cannot be viewed as objectively defined properties of an environment, but rather as properties of the environment that arise in relation to a category or class of agents that have shared capabilities to act (effectivities). In order to make the point that constructivist learning is not necessarily strictly individual, we next describe the ecological psychology construct of affordance-effectivity “duals” and suggest that they should be considered nested within situations to illustrate the need to account for more than individual “constructions” in constructivist learning. Additionally, we wish to highlight that the intentions of the instructional designer and the “taken as shared” (Cobb et al., 2001) goals of a community of practice should be key elements of any situation model.

The term affordances has been applied in the education literature to describe the properties of the environment that permit certain activities (e.g., Greeno, 1994). For Gibson, the idea of affordances meant those invariant properties of the environment that specified, to a particular agent, the possibilities for action – in short, the functional value of the environment (Gibson, 1977). For Gibson whose focus was primarily on visual perception, affordances were specified in the information field, specifically the visual flow field. Implicit in Gibson’s analysis was the fact that these properties of the environment were for a specific agent or class of agents, acting within a specific space-time, not for all agents for all times. So rather than being able to pre-specify, in an objective sense, the affordances of a particular learning environment once and for all, it was necessary to “situate” the idea of affordance as specific to a particular class of agents, in order to recognize the co-determined nature of the concept.

So for our analysis of situations, an affordance is not an inherent property of the environment alone ... only of its relationship to a specific class of



agents with specific goals and abilities (termed “effectivities” by Shaw and Turvey, 1999). A common example is that a door knob has the affordance of “turnable.” But it only has this affordance for agents with the ability to turn the handle (certain dexterity and hand shape). A doorknob does not have the “turnability” affordance for a dog (no hands), or even an infant (insufficient strength) – agents who do not have the effectivity of turning knobs. So an affordance is co-determined by properties of the object in relation to the properties of the agent. Likewise, it would be impossible to specify the skill (effectivity) of knob-turning, without describing an environment that had the affordance structure of turnable knobs. This idea of co-determination leads to an important description of terms as “duals” that can be described more precisely and modeled mathematically within the ecological psychology framework (e.g., Shaw et al., 1992).

Given the description of ontological descent, we would further assert that the actual pick-up of affordances must be modeled in relationship to the learner’s intentions. While a doorknob may have the affordance “turnable” for normal adult humans, an analysis based on ecological psychology suggests that a person may only detect that affordance when they have adopted a relevant goal (e.g., getting out of the room). Thus, there may be an infinite number of potential affordances of any realistic context (including salad making), but the “trick” of modeling is to model those that are most likely to be detected by learners given the goal constraints of the situations that emerge. This “situational” analysis means that although information specifying an affordance may potentially be available (along with a nearly infinite amount of other information), only agents with particular intentions and particular effectivities would be expected to “pick up” (or detect) such information on a given occasion.

In the terms of the Akras and Self (this issue) affordance model, the model of a particular situation type (e.g., **salad-making**), affords for **learner-a**, the generation of entity **tomato is part of the salad**, through the event **add-ingredient-to-salad** process. But such an affordance for us must also be described as pertaining to a class of **leaners<sub>a-n</sub>**, that have particular **effectivities (representing/cognitive ability and making salad/ physical ability)**. In addition, as stated earlier we would assert that such an affordance would only be actualized (perceived and acted upon) on occasions in which this affordance was pertinent to attaining the individual’s currently adopted goal, **learning’s-intentionality in state (goal = make salad)**, and might not be realized if other intentions were constraining action (e.g., **learner’s-intentionality in state (goal = understand the ILE programming)**).

Since affordances and effectivities are duals (co-determined), it is not as simple as it may seem to say that the information side of the equation

(affordances) and the control side (effectivities) are equivalent to potentials for action specified by the environment (affordances) and potentials to act associated with an agent (effectivities). This would leave both components as unrealized potentials, and no dynamics would ever emerge (Shaw and Turvey, 1999). So there is something more than a simple ability to act that we wish to convey with the term effectivity. Rather than solely being long-term stable properties of an individual (e.g., compare the term spatial ability or mechanical ability), effectivities are assembled in a particular situation (constrained within space-time) given a particular intention. To use Shaw's words, affordances propose while effectivities dispose (Barab et al., 1998). Effectivities have the added property of dissipating the potential by actualizing it in a particular instance.

Since affordances are co-determined properties that specify the functional value of things in the environment, it is possible to change the level of analysis from the individual to the instructional designer, or even to the community of practice. In the first case, affordances would be co-determined by the goals and effectivities (abilities to act) of the instructional designer, and in the second case, affordances would be co-determined by the "taken as shared" goals of the community and their collective ability to act. We believe these superordinate nested perception-action duals are critical to any full model of situation or context.

With the dual nature of affordances and effectivities thus described, it is possible to clarify our contention that superordinate levels of intentionality must be modeled to get a full description of context or situation. Figure 2 describes a situation in which an instructor is present while a student interacts with an ILE. In this case there is an interface between the instructor and the student that permits them to establish a shared intentionality.<sup>4</sup>

The extent to which the student adopts the goals of the instructor is probabilistic, but absolutely essential to constrain any model of affordances. For example, one could imagine a computer science student interested in ILE's who begins using the salad making tutor described by Akhras and Self (this issue). In this case such a student would not share the goals (learning to make salad) that the instructor presumed. Any ILE reasoning would then appear misguided at best about how the student was using the system. Instead of wanting to learn to make salad, the students' intentions would be guiding them along a path toward understanding how rules and "situation affordance" models were being constructed within the ILE, represented, and applied to reasoning strategies. Here the description given in Figure 2 further applies in that the intentionality of the instructional designer (embedded in the system) is also not appropriate for the student interaction that is unfolding. A full description of the context would need to accommodate the process

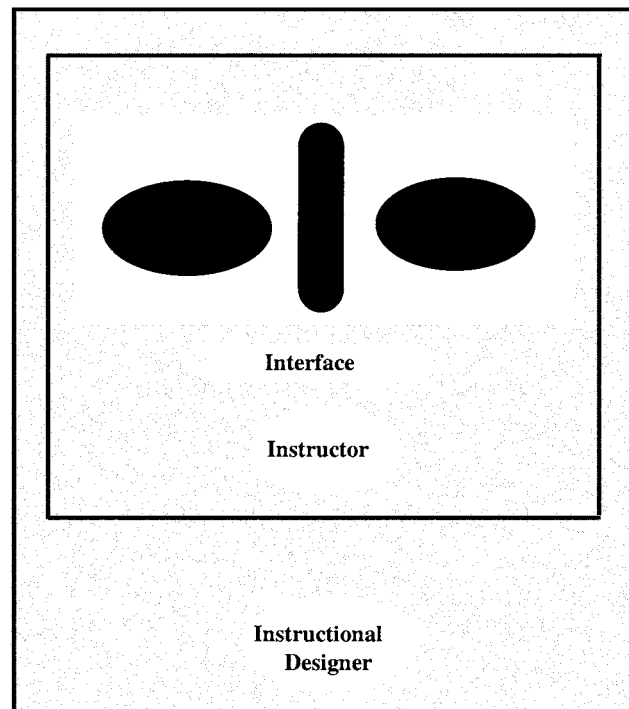


Figure 2. Nested instructional “duals” (adapted from Shaw et al., 1997).

by which the instructional designer would observe this new use (by the computer science students) and adapt and modify the system to account for this orthogonal set of goals.

Figure 3 depicts our contention that the goals and intentions of a community of practice (in our example both the community of chefs and the community of computer programmers) would need to be accounted for in any full analysis of situation or context. While learning is going on, it inevitably occurs within some superordinate social context. Most importantly, this level of intentionality imposes critical constraints on what constitutes a “legitimate” constructed understanding of the learning domain. So for the surgeon constructing their understanding of anatomy (mentioned earlier), this level of constraints would impose the “taken as shared” perspective on the functional value of some understandings (including a shared vocabulary to be used by medical treatment teams) which would allow the ILE to judge the correctness of some responses. In addition, higher order constraint would provide for instances in which new knowledge is still emerging within the medical community, such that the functional value of today’s practices can ultimately be judged against their ultimate functional value. This correctness,

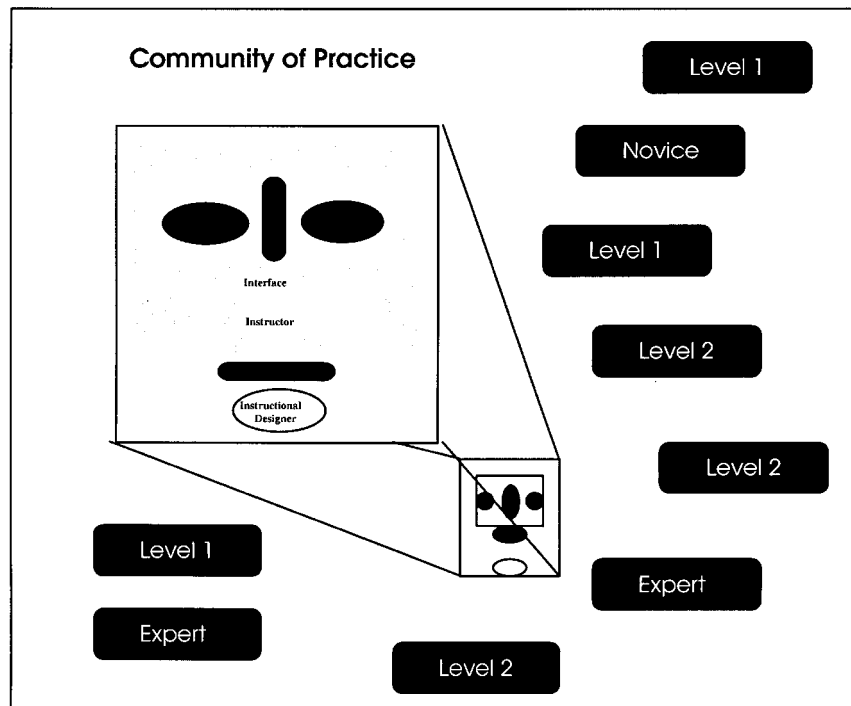


Figure 3.

however, would not be based on objectivist truth, but rather on the socially-defined function value of the understanding and the constraints imposed by ontological descent.

In summary, rather than a single learner model of constructivism, our perspective based on ecological psychology suggests that a complete situation model must account for the nested levels of intentionality present on any occasion (for a particular situation). Only by providing for such co-determined duals at multiple simultaneous levels can the model begin to account for the complex nonlinear dynamics that unfold during specific instances of learning with ILE's.

### **The perception-action cycle: One does not learn from affordances alone**

Akhras and Self (this issue) attribute substantial learning and developmental power to situation types and write:

This leads to particular situation types being able to afford to a particular learner the development of courses of interaction that possess particular

properties (p. 38) and they state, Therefore, as an example of how a situation type may afford to a learner the development of particular patterns of interaction, we can say that the situation type **salad-making** affords to **learner-a** generating the entity **tomato is part of the salad** through the event **add-ingredient-to-salad** (p. 36).

and although Akhras and Self (this issue) state that:

... affordances are located neither in the environment nor in the learner. Instead, they are intended to capture units of analysis that refer to both the environment and the learner in a complementary way (p. 35).

there appear to be two components we would add to this model. First, we have asserted that the learner's goals will determine the extent to which the affordances that the designers model will be the same as the affordances detected by the learner.

But in addition, we would assert that learners' actions, themselves, must be part of the situation type. Thus for example, the situation model, "**event:** learner-a can slice-ingredient" (p. 19), is a potential, but not to the actual slicing of the tomato.

We would like to add an equal emphasis on the control side of the perception-action equation, and not only on the potentialities represented in the affordances (information side). We would contend that **behavior:** learner-a slices ingredient should be added to the model such that the manifest doing of some actions enters in to the situation model as an entity. This would be consistent with the reciprocal relationship we believe exists in the perception-action cycle. The occurrence of this behavior would then lead to a recursive process in which the affordances would now be re-defined with the emergence of a newly "tuned" perceptual system. In short, the actual sliced tomatoes not only present a new system of affordances in themselves, the act of slicing may lead to development and enhanced perception of the learner, such that **perceptual attunement:** learner-a differentiates thin slices from thick slices for which the situation model must now be updated.

Consider a traditional lecture presented at a major university by a charming and eloquent senior professor. In this "context or situation" one might be drawn to simplify the situation model by looking at the information field (instructor handouts, the lecture delivery, and the textbook) as the sole source for learning. Certainly learning takes place in such contexts, as we have all benefited from such learning environments. Thus one would only need to model the affordances (of course, accounting for their dual nature that customizes the affordance construct to the effectivities of a particular agent as we described above). But learning, perhaps best described as perceptual tuning (Young et al., 2000), may be equally impacted by exercising control of

the environment and perceiving its effects. Relatively simple generative acts such as note taking (the actual writing) may substantially impact learning (e.g., Wittrock, 1990). It may be the energy expended in action that drives the autokatekenetic systems of learning and development (Barab et al., 1999, Lemke, 2000).

Then consider learning environments that allow substantially more activity than lectures, such as problem-based, project-based, and learning by design. In such learning environments, it is possible to propose a substantial role for activity. This was a critical part of Gibson's (1986) seminal analysis of visual perception. For example, he unravelled the mysteries of how we perceive objects with occluded surfaces as whole objects, simply by pointing out the simple fact that moving our heads back and forth provides information in the dynamics under the control of the learner that enhance perception

A point of observation is to be thought of as moving through the medium to and fro, back and forth, often along old paths but sometimes along new ones. Displacements of this position are reversible and are reversed as its occupier comes and goes, even as she slightly shifts her posture. Any face of facet, any surface of the layout, that is progressively hidden during a displacement is progressively unhidden during its reversal. Going out of sight is the inverse of coming into sight. Hence, occluding and occluded surfaces interchange. The occluding ones *change into* (emphasis his) the occluded ones and vice versa, not by changing from one entity to another, but by a special transition. (p. 79)

As it was that the control/action side was essential for understanding vision, so it is with lecture situations that the affordance/information field impacts learning, but the generation of responses, the control/action field, may be an equally critical attribute of the situation that impacts learning and development. With learning defined as the education of attention and intention, it seems reasonable to propose that actions as well as perceptions tune the attention of learners to enable them to detect additional affordances of their environment. Further, we would optimistically add that instructional designers can determine that engaging in some behaviors have higher probabilities for attuning the individual to new possibilities for action, than others. So for Gibson's analysis of occluded surfaces, there are some head movements that clearly reveal the nature of occluded objects while others are less revealing. And for lectures, some student behaviors may have high probabilities of leading to new understandings (selective note taking, active listening, representing) while other (writing every word) may be less educative.

### **A final word**

In conclusion, we believe the Akras and Self (this issue) approach to modeling situation types is a productive pursuit. We take it as a given and seek to expand on their theoretical and conceptual model in ways consistent with our understanding of thinking and learning from an ecological perspective. We believe that any model of learning must acknowledge that dynamics come in to play at a variety of space-time scales and we offer Shaw's description of ontological descent as a means for organizing the constraints that are at work for intentionally-driven learners. We also find that relying on constructivism does not of itself provide an adequate alternative to the objectivist "truth" that could guide a situation model to interpret learner behavior. We propose the ecological alternative of agent-environment, perception-action duals that rely on functional value and acknowledge socially-defined constraints. Finally, we propose that models of affordances are not enough, that the control/action side of the perception-action dual should be given equal representation in any model of situation, context and interaction.

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### **Notes**

1. It must be acknowledged that the term situation is not used in a consistent manner within and across discussions. We have chosen not to detail our own formal definition here but wish to make note of this for ongoing future discussions (see also Engestrom & Cole, 1997 for a brief discussion). The term 'situation' can be defined in a more formal sense within a full theory of situated cognition or in the colloquial sense of contextual circumstances surrounding any activity. We wish to use the colloquial meaning to establish our point concerning a full situation analysis, but acknowledge that a formal definition remains to be adopted by the field.
2. Given a system of a single linear equations there are  $n - 1$  degrees of freedom, where  $n$  is the number of variables in the equation.
3. In broader terms a system of linear equations loses a degree of freedom for each linearly independent equation in the system. Given a system of linear equations of  $n$  variables,

counting degrees of freedom can be used to determine if a solution is possible. If  $m < n$  there are still  $n-m$  degrees of freedom available, and so the system cannot be solved for all  $n$ . If  $m \geq n$  there are no degrees of freedom available, so the system can be solved for all  $n$ . Now, by assigning values to  $x$  and  $y$  we have actually specified a system of 3 linear equations (Equations 1, 2 and 5) of 3 variables, leaving 0 degrees of freedom. This guarantees that  $z$  would be fully specified without further analysis.

4. See Shaw, et al.'s., 1992 description of the "intentional spring" for a mathematical strategy for characterizing such "duals of duals" from the ecological psychology perspective.

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