

2 Practices of distributed intelligence and designs for education

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Introduction

Widespread conceptions of learning and reasoning invoke “intelligence” largely as a property of the minds of individuals. This belief is prevalent in educational settings, which are concerned largely with solitary intelligence. Intelligence, they say, is what testing firms test and, increasingly commonly, what schools need to be held more accountable to measuring and improving.

Problems lurk in these assumptions. Anyone who has closely observed the practices of cognition is struck by the fact that the “mind” rarely works alone. The intelligences revealed through these practices are distributed – across minds, persons, and the symbolic and physical environments, both natural and artificial. Gregory Bateson remarked that memory is half in the head and half in the world. In this chapter, I will first lay out the central ideas of the distributed-intelligence framework and then provide a background to its development, before closing with considerations of some implications for education. How we think about these relations may change what we

Portions of this chapter were originally slated to appear in a book edited by David Perkins and Becky Simmons of Harvard University’s Educational Technology Center. Plans for that book subsequently foundered, and portions of my essay (Pea, 1988) appear here as a necessary pretext to subsequent work. Previous papers on this theme were first presented in April 1988 to the First Annual Cognition and Education Workshop, Bolt, Beranek and Newman, Inc., Cambridge, Massachusetts, and at the 1988 Cognitive Science Society Meetings. Related work was described at the 1989 Social Science Research Council Conference on Social Aspects of Computing (in which Gavriel Salomon and David Perkins participated) and in the 1990 American Educational Research Association Symposium on Distributed Intelligence, which led to the plan for this book. I am indebted to Christina Allen for provocative discussions of distributed intelligence, especially concerning design and the roles of human desires.

do with technologies in education – not only computational media, but also social technologies for supporting learning such as guided participation or peer collaboration and learning/teaching materials more broadly. While providing few answers, I hope to provoke new questions and inquiries, for distributed intelligence is not a theory of mind, or culture, or design, or symbol systems and their impact on human thought so much as it is a heuristic framework for raising and addressing theoretical and empirical questions about these and other topics.

While the relevance of these concepts is not restricted to learning in mathematics, science, and technology, I will often use examples and issues in these fields for making my points, since the roles for distributed intelligence perhaps stand out in greater relief in these domains than in other areas of learning, education, and work.

The nature and concepts of distributed intelligence

Knowledge is commonly socially constructed, through collaborative efforts toward shared objectives or by dialogues and challenges brought about by differences in persons' perspectives. Intelligence may also be distributed for use in designed artifacts as diverse as physical tools, representations such as diagrams, and computer–user interfaces to complex tasks. In these cases, intelligence is often distributed by off-loading what could be elaborate and error-prone mental reasoning processes as action constraints of either the physical or symbolic environments.

On close inspection, the environments in which humans live are thick with invented artifacts that are in constant use for structuring activity, for saving mental work, or for avoiding error, and they are adapted creatively almost without notice. These ubiquitous mediating structures that both organize and constrain activity include not only designed objects such as tools, control instruments, and symbolic representations like graphs, diagrams, text, plans, and pictures, but people in social relations, as well as features and landmarks in the physical environment. Imagine the absence of the following resources and the detrimental effects of that absence on the activities to which they may contribute intelligence: keyboard letters, labels on instrument controls, everyday notes, well-placed questions, the use of space

to organize piles of materials on a desktop, the emergent text in a written composition one is constructing. These everyday cases show the active and evolving structuring of the material and social environments to make them a repository of action mediators. Unlike other species, such as Simon's (1981) ant on the beach, whose complexity of behavior is determined more by the shape of its environment than by its mental contents, humans have desires that lead them to recraft their environments to carry out aspects of reasoning, to make reminders for action, and to get help from others. When talking about distributed intelligence, then, I mean that resources in the world are used, or come together in use, to shape and direct possible activity emerging from desire. This is not to claim, of course, that *all* intelligence is or can be so distributed, but that there is a constitutive trend in this direction to be found in cultural history, ontogenesis, and the microgenesis of activity.

The distributed-intelligence orientation that I describe, which takes these observations as central data about cognition, stands in sharp contrast to the common focus on "intelligence" as an attribute of individuals, carried primarily in internal transformations of mental representations of symbols for goals, objects, and relations. Theories of education building on these notions are concerned largely with solitary intelligence, decontextualized from its uses in activities beyond the educational. Analyses of our designs for such distributions may be more revealing for understanding cognition than are studies of the formation and transformation of mental representations that have come to define cognitive science and educational studies based on this field.

Some key interrelated concepts I will use require clarification. These include "intelligence," "activity," "distributed," "means–end adaptivity," "affordances," and "desire."

Intelligence as distributed and manifest in activity

The primary sense of distributed intelligence arises from thinking of people in action.¹ We begin with activity, expressing

¹ I take the work of Leont'ev (1978a, b) on activity theory as arguing forcibly for the centrality of people-in-action, activity systems, as units of analysis for deepening our understanding of thinking. On related philosophical grounds, Wartofsky's (1979,

action rather than a state of being. In such activity, we see the *configuring* of distributed intelligence. Activity is enabled by intelligence, but not only intelligence contributed by the individual agent. When I say that intelligence is distributed, I mean that the resources that shape and enable activity are distributed in configuration across people, environments, and situations. In other words, intelligence is accomplished rather than possessed. The intentionality of activity may originate with the agent's desires or the hopes of a designer wishing to bring the affordances of a new artifact into the configuration of another agent's activity. While it is people who are in activity, artifacts commonly provide resources for its guidance and augmentation. The design of artifacts, both historically by others and opportunistically in the midst of one's activity, can advance that activity by shaping what are possible and what are necessary elements of that activity.

What is meant by *intelligence* as distributed? I use the phrase "distributed intelligence" rather than "distributed cognition," because *people*, not designed objects,² "do" cognition. Yet I want to capture the important fact that intelligence, which comes to life during human activities, may be crafted. There are both social and material dimensions of this distribution. The social distribution of intelligence comes from its construction in activities such as the guided participation in joint action common in parent-child interaction or apprenticeship, or through people's collaborative efforts to achieve shared aims. The material distribution of intelligence originates in the situated invention of uses for aspects of the environment or the exploitation of the affordances of designed artifacts, either of which may contribute to supporting the achievement of an activity's purpose.

Activity is achieved in means-end adaptations. These adaptations may be more or less successful. The focus in thinking about distributed intelligence is not on intelligence as an abstract property or quantity residing in minds, organizations, or objects. In its primary sense here, intelligence is manifest in activity that connects means and ends through achievements. I also do not mean "intelligent" in

1983) historical epistemology also highlights external action, or praxis, as the focus of understanding for psychological development.

² I leave designed objects such as "artificially intelligent" computer software aside for the moment, concentrating on noncomputational objects. Whether computer programs engage in cognition is not a topic of this chapter.

the generic folk value sense, so I reject "distributed foolishness" or "stupidity" as antonyms of "distributed intelligence." These are values at the evaluation level of the action itself (e.g., "Bank robbing is a stupid and not an intelligent act") or in terms of norms regarding, for example, the efficiency of means-end adaptivity, as in "Using a rock to hammer a nail is stupid; using a hammer is more intelligent."

Affordances

How do tools serve as artifacts of distributed intelligence, carrying along with them new opportunities for contributing to activity, as defined by a community of users of such tools? I begin this inquiry by noting the focal relevance of works by Vygotsky, Simon, and Gibson. Each of these theorists considered questions about the distribution of intelligence between the world and the mind to be fundamental. Vygotsky (1978) placed great emphasis on the ways in which the character of social interactions and externally mediated action makes explicit certain processes that come to be internalized in the private thought of the individual. In Simon's (1981) seminal work, *The Sciences of the Artificial*, he questions whether what we often consider the complexity of some act of thought may have more to do with the complexity of the environment in which action takes place than with the intrinsic mental complexity of the activity. In pointing to the mind-environment interface, Simon suggests looking at problem solving as distributed between mind and the mediational structures that the world offers. In Gibson's (1979, 1982) work on the ecology of perception, the notion of "affordances" of objects that link perception and action is central. "Affordance" refers to the perceived and actual properties of a thing, primarily those functional properties that determine just how the thing could possibly be used. Less technically, a doorknob *is for* turning, a wagon handle *is for* pulling.

Research examining the concept of affordances is critical if we are to build a science of distributed intelligence and a more flexible design orientation to the practices of education. For many of the hoped-for goals of education, we presuppose the success of the social constructability of affordances – that one can get a learner to attend to

the pertinent properties of the environment, or the designed object, or the inscriptional notations, such that the learner can join in to contribute to distributed intelligence in activity. For a given activity, and the various means for its achievement, there can be considerable variation in the ease with which one can show a learner how to exploit those means to form a system of distributed intelligence for achieving that task. This will vary with the learner's background experiences, the obviousness of the mapping between the learner's desire or goal, and the assimilation of the artifact as means toward it. Such a meeting of intentionality and artifact in activity is thus not simply the direct perceptual pickup of the affordance structure of the object or notation, as radical Gibsonians would have it. Culture and context contribute to its achievement.

Norman (1988) has done a great service both to the field of design and to psychology in developing Gibson's insights on affordances (which largely underplayed the cultural factors involved in learning to use humanly designed objects) into what he calls a "psychology of everyday things." Norman offers many examples – microwave ovens, videocassette recorders, car instrument panels, slide projectors, even water faucets – to show how affordances of objects deeply and often unnecessarily restrict their *accessibility* to the ordinary human. The point is that better design of artifacts would make it easier to accomplish certain functions. One would like to be able just to look and see what to do, and then do it, without instruction, without manuals, without complex deductions. Such "efficiency" of action is also a tacit objective of cognition in practice. Everyone can imagine a few examples of powerful representational tools that are not obvious in function (e.g., the static x - y coordinate graph, static ray diagrams in optics) and make apparent that what Norman calls the "psychopathology of everyday things" may carry over only too well to an account of the psychopathology of instructional artifacts and representations in mathematics and science.

Lave (1988) offers many examples of "smart tools" that we may point to as illustrations of the everyday presence of such distributed intelligence. She describes how measurement activities are often achieved with special-purpose "stashes" of numerical information embodied in measuring instruments. Examples include such invisible cases as the dime-store thermometer, yardstick, auto speedometer,

and home thermostat. Many of these objects have become "mythic," as Roland Barthes (1972) uses this term, in that they have become so deeply a part of our consciousness that we do not notice them. Turned from history into nature, they are invisible, un-"remarkable" aspects of our experiential world. A large number of such "smart objects," especially for measurement and for calculation, but also as reminding devices, are appearing. They are becoming especially prevalent as microprocessors enter the fabric of everyday activities by the tens of millions. Finding marketable niches for such efficiency, many of these devices reify common problem formats and automate solution-finding procedures. Examples include jogger pulse meters, automatic street locators, currency exchange calculators, world-time clocks, and weight-loss calculators.

These tools literally carry intelligence *in* them, in that they represent some individual's or some community's decision that the means thus offered should be reified, made stable, as a quasi-permanent form, for use by others. In terms of cultural history, these tools and the practices of the user community that accompany them are major carriers of patterns of previous reasoning. They may contribute to patterns of distributed intelligence configured in activity. They may now be used by a new generation with little or no awareness of the struggle that went into defining them and to adapting their characteristics to the tasks for which they were created. The inventions of Leibniz's calculus and Descartes's coordinate graphs were startling achievements; today they are routine content for high school mathematics. But as such tools become invisible, it becomes harder to see them as bearing intelligence; instead, we see the intelligence "residing" in the individual mind using the tools. This encapsulation of distributed intelligence, manifest in such human activities as measuring or computing, may arise because we are extraordinarily efficient agents, always trying to make what we have learned works usable again and again. We deploy effort-saving strategies in recognition of their cognitive economy and diminished opportunity for error (Kusterer, 1978; Scribner, 1986).

The individual still has a primacy in activity, of course. But the distributed-intelligence framework sees a much more substantial haze around the boundary of the person and shines the light of attention on the more invisible intelligence in the artifactual, physical,

symbolic, and social surrounds, as brought into relief in the configurations of distributed intelligence by which activity is achieved.

To sum up, knowledge is often carried in artifacts as diverse as physical tools and notational systems such as algebraic equations. This knowledge may come to be exploited in activity by a new learner through a variety of genetic paths: through observations of use by other humans and attempts to imitate it, through playful discovery of its affordances in solitary activity, and through guided participation in its use by more knowledgeable others. And the affordances of such artifacts may be more or less difficult to convey to novice users of these artifacts in the activities to which they contribute distributed intelligence.

Desires

Our last major concept is “desire.” What initiates activities and designs of distributed intelligence? I find it useful to begin with Norman’s (1988) approximate model of the structure of activity. His account of seven stages of action proceeds through four stages of execution – forming a goal, forming an intention, specifying an action-sequence plan, and executing an action, and three stages of evaluation – perceiving the world state after the action, interpreting the world state, and evaluating an outcome of action in relation to the goal. Since I believe that the concept of “goal” common in cognitive science presupposes commitment to greater articulateness and mental representation than the diffusely specified *desires* that often lead to action,³ it will be important to develop some basic account of desires in order to think about the shapes of distributed intelligent activity that emerge for people.

How do people’s *desires* for a particular situation shape both their interpretation and their use of resources for activity? Human use of distributed intelligence in the designed environment to achieve activity goes far beyond either situational determinism or a decoding

³ Agre (in press), Suchman (1987), and Winograd and Flores (1987) have provided compelling arguments on this point, rooted in phenomenological works by Heidegger, Husserl, and Schutz. Their arguments on the primacy of situated action and the derivative nature of mental representation also rest on a shift of attention toward person-acting-in-setting-with-others-and-artifacts-with-cultural-histories as the to-be-explained rather than individual knowledge.

of the intentions behind the design of objects. While one who is using a hammer to strike a nail is, in the achievement of that activity, in an important sense collaborating with its designer, there is more to it than this. The process also involves the interpretation of resources and relationships for creative and novel activity (Schön, 1983). Resources of the world offer potential relationships, constrained by their affordances, that may not at all be mentally represented prior to a situational perception of their meaning. Their functional roles as components of a configuration of distributed intelligence may arise only in the course of desire-driven initiatives by an actor. This observation is profoundly true for designers, who are continually creating new objects and environments, interpreting their meaning, and revising their designs accordingly (Allen, 1988). Intelligence is contributed in each moment by the ways in which people interpret the things they are experiencing. We need to understand more fully the genesis of human desires, because people create, invent, and innovate as they create or act in designs for distributed intelligence. They do not simply act in habitual, static ways. The interpretation, relevance, and meaning of resources available for activity are shaped by the desires with which people come to situations.

Some basic distinctions are valuable for beginning to think through a useful taxonomy of desires. We can identify a small set of basic desires, not intended to be exhaustive, each of which constitutes a kind of experiential “moment” that a person brings to a situation for achieving activity:

1. With a *task* desire, one has a clear goal and intention, and the need is to specify an action with a particular means. If I am freezing in a cabin, my task desire for warmth may make the affordance of a chair for burning much more salient than its affordance for sitting. If my task desire were different, different properties of the chair would matter.
2. With a *mapping* desire, one falls short of mapping the achievement of projected activity back into the specific action to be taken with an available means. I know this tool may be used to achieve the activity, but I am uncertain of how the distributed-intelligence resources need to come together in design. In Norman’s terms, this is a gap to be closed from intention to specification of action. I have available an outline processor instead of a typewriter for writing – my

