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COMMENTARY

The Social and Technological Dimensions of Scaffolding and Related Theoretical Concepts for Learning, Education, and Human Activity

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I am perhaps not the only one who feels that the concept of scaffolding has become so broad in its meanings in the field of educational research and the learning sciences that it has become unclear in its significance. Perhaps the field has put too much of a burden on the term, and we need a more differentiated ontology to make progress. Perhaps scaffolding has become a proxy for any cultural practices associated with advancing performance, knowledge, and skills whether social, material, or reproducible patterns of interactivity (as in software systems) are involved. This is surely too much complexity to take on at once. Given these burdens at the level of a scientific account of learning by the individual, I feel it is premature to be extending scaffolding considerations by metaphorical extension to the level of a whole classroom of learners or even to a cultural level, as Davis and Miyake (this issue) suggest in their introductory essay. I first see whether I can garner some clarifications and leverage from uses of the term *scaffolding* for specific instances and classes of its uses by individual learners (where the articles in this issue focus their attention).

As with many such concepts that are felt to have useful power in theoretical and practical schemes, it will be worthwhile to do some historical excavation, identify and circumscribe the early uses and roots of the concept, and then determine

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whether in the rich body of work that has developed since its origins roughly 30 years ago one can craft a conceptual map relating scaffolding and its many affiliated concepts such that the vitality of the issues raised in its initial conceptualization can be preserved and even extended.

My goals for this article were to first provide a personal view on the history of scaffolding and related concepts in its semiotic field and to then develop a framework for what I believe to be its definitional core and contrastive terms and the primary issues and opportunities they present for us as learning scientists and educators. I then consider the contributions made and the issues raised in this issue's collection of articles in terms of this framework. Reading the articles themselves will be important for the reader, as my goal is not to review them here but to reference them. Collectively, the four articles by Reiser, Quintana et al., Tabak, and Sherin, Reiser, and Edelson (this issue) provide illuminating conceptualizations that help advance the theory of scaffolding for instructional support, primarily with a focus on learning how to do scientific inquiry in the middle to high school grades. They offer a distinction between "structuring" and "problematizing" mechanisms of scaffolding for student work (Reiser, this issue), a scaffolding design framework encompassing an impressive array of categories around different components of scientific inquiry illustrated with many software systems (Quintana et al., this issue), the concepts of "distributed scaffolding" and "synergy" between different components of distributed scaffolding (Tabak, this issue), and an analytical framework arguing that scaffolding should be conceived of as a comparative analysis to be performed on learning interactions (Sherin et al., this issue) rather than software features or situations. There is much to be learned from these articles, as they provide a synoptic view of scaffolding research in science learning.

I recall first becoming aware of the concept of scaffolding when I was a doctoral student in Jerome Bruner's laboratory on South Parks Road in the Department of Experimental Psychology at Oxford University around 1975. The context was one in which a number of graduate students, postdocs, and visiting fellows (including Catherine Urwin, Michael Scaife, John Churcher, Alan Leslie, Chris Pratt, Alison Garton, Renira Huxley, Kathy Sylva, and later visiting students Alison Gopnik and Susan Sugarman) were studying the ontogenesis of language and thought and especially the emergence of syntax from the early protolanguage and single word period of child language. Yet others were studying imitation, perception, play, and other developmental phenomena. We regularly read papers together, had a lively weekly seminar series, and reviewed and analyzed video data and its interpretations together.

The term scaffolding was one introduced by David Wood with Jerry Bruner and Gail Ross in an article published in 1976 and the related idea "in the air" among our Oxford group was one that Jerry called "formats." The notion was that one of the potential explanations for how it is that babies acquire meaning in early parent–child interaction is that there are regularly structured situations in which the range of meanings is actually quite limited and that these simple formats provide a highly constrained situation in which the child can bootstrap some of the conventions of turn taking and meaning making with words that are required of a language user (e.g., Bruner, 1975a, 1975b, 1977). Bruner and Sherwood (1976) illustrated this line of argument using data from peekaboo interactions between a mother and child.

In Wood et al.'s (1976) article, the term scaffolding was first used, and it describes how an interaction between a tutor and a child concerning how to construct a wooden pyramidal puzzle employs "a 'scaffolding' process that enables a child or novice to solve a problem, carry out a task or achieve a goal which would be beyond his unassisted efforts" (p. 90).

Formats for early language thus provided a form of scaffolding for learning to use words and the acquisition of meaning.

In both of these conceptualizations, whether mother–infant interaction in the service of language development or for the development of the puzzle-solving behaviors described in the Wood et al. (1976) article, the first thing to notice is that the situations of learning are neither formal educational nor "designed" in the traditional sense of the term (even if the puzzles were designed, as Tabak, this issue, notes). Such interactions as we were studying were ones we conceived to be naturally occurring in an informal context and an expression of one of the socioculturally grounded activities typical of at least some families in Western societies. Needless to say, the scaffolding achieved in these mother–infant encounters was not computer mediated. The work that the concept scaffolding is intended to do in these psychologists' accounts of human development is to bring to one's attention the function that particular behaviors on the mother's part appear to play in enabling the performance of a more complicated act than would have otherwise been possible. In this sense, scaffolding appears to be an apt turn of phrase as both noun and verb—*noun* because it is a structure, guided in specific form by tacit assessment of a child's independent capabilities and needs, and mounted temporarily on the learner's behalf until the child can self-sufficiently produce the behavior on his or her own—and *verb* because scaffolding is also a process because different aspects of an activity will need to be scaffolded in the conduct of performance over time unless independent performance is achieved. If the parent continued to do such structuring once the child becomes capable of autonomous activities, one would find it strange.

It was also current at the time for our Oxford Group and others such as Wood's group at Nottingham to be reading and thinking about the philosophy of language and accounts more broadly of the psychology and development of language. We were reading attempts by Patricia Greenfield (Greenfield & Smith, 1976), John Dore (1972), Elizabeth Bates (1976), and others to make sense of how it is that infants come to speak not only single words but also eventually sentences. So accounts of how to do things with words (J. L. Austin), of speech acts (J. Searle), of word meaning-as-use (L. Wittgenstein), and of functional accounts of language in the development of thinking (Vygotsky, G. de Laguna) were of vibrant interest to us. We wanted to know how the baby cracked the linguistic code and became able to do productive things with words in interaction, and we were unsatisfied with Chomsky's (1966) nativist account of language acquisition.

It is in this vein that the role of Vygotsky's (1978) concept of the zone of proximal development (ZPD) in conceptualizations of scaffolding is noteworthy. Defined as the zone of activity in which a person can produce with assistance what they cannot produce alone (or can only produce with difficulty), the ZPD concept depended on a view of human development that had a number of important and distinctive properties.

The first central property is Vygotsky's (1962) sociohistorical conceptualization of the development of language and concepts. Unlike Piaget, who was a genetic Kantian arguing for the child's construction of the necessary categories of experience (time, space, causality) from largely individualistic interactions with the physical and representational worlds (Toulmin, 1972), Vygotsky as a Marxist was quite apposite to the view that human nature is a given. As Marx Wartofsky (1983) famously pointed out, there is solid historical evidence of the world's construction of the child as much as the child's construction of the world: "Children are, or become, what they are taken to be by others, and what they come to take themselves to be, in the course of their social communication and interaction with others" (p. 190). I took this argument to provide a vital issue for human learning augmented with information technologies:

> According to this theory, human nature is not a product of environmental forces, but is of our own making as a society and is continually in the process of "becoming." Humankind is reshaped through a dialectic, or "conversation" of reciprocal influences: *Our productive activities change the world, thereby changing the ways in which the world can change us.* By shaping nature and how our interactions with it are mediated, we change ourselves. (Pea, 1987, p. 93)

Second, as Vygotsky would have it, psychological development progresses from an interpsychological to an intrapsychological plane—it is through the child's experiences of participating in activities that are initially externally accessible that the structures and content of mental life that can be played out internally become possible, an account reminiscent of Wittgenstein's (1958) conception of learning as participation in "forms of life":

> The very essence of cultural development is in the collision of mature cultural forms of behavior with the primitive forms that characterize the child's behavior. (Vygotsky, 1981, p. 151)

It was perhaps not until Michael Cole, John-Steiner, Scribner, and Souberman's translation and publication of selected Vygotsky essays in the landmark 1978 volume, *Mind in Society: The Development of Higher Mental Processes,* prompting the philosopher Stephen Toulmin (1978) to call Vygotsky "the Mozart of Psychology," that the fertility of the ZPD concept was made broadly evident to Western psychologists and educational theorists. Michael Cole collaborator Joe Glick's (1983) chapter on "Piaget, Vygotsky and Werner" helps set a context for the arrival of this work on the American scene and why it took root so quickly in an intellectual environment in which "fixed capacity" conceptions of intelligence were losing favor. Glick distinguished "Vygotsky I" of *Thought and Language* (Vygotsky, 1962), a book that Vygotsky assembled himself during his lifetime, and "Vygotsky II" of *Mind in Society* (1978), an editorial construction selected for its contemporary relevance to American psychology. (I cannot explore this distinction here, but I recommend it to interested readers, especially those not enamored by the "internalization" metaphor with which Vygotsky has come to be identified whereby cultural influences are interpersonally inculcated and subsequently "internalized.")

> In *Mind in Society* (Vygotsky II), the underlying conceptual object appears to be the manner in which sign systems transform organism–environment relations and the means by which mind becomes socialized (Glick, 1983, p. 43).

Glick (1983) noted that the editors depicted these concepts by making several observations after first quoting Vygotsky:

> "The specialization of the hand—this implies the tool, and the tool implies specific human activity, the transforming reaction of man on nature...the animal merely uses external nature, and brings about changes in it simply by his presence; man, by his changes, makes it serve his ends, masters it. This is the final, essential distinction between man and other animals." Vygotsky brilliantly extended this concept of mediation in human–environment interaction to the use of signs as well as tools. Like tool systems, sign systems (language, writing, number systems) are created by societies over the course of human history and change with the form of society and the level of its cultural development. Vygotsky believed that the internalization of culturally produced sign systems brings about behavior transformations and forms the bridge between early and later forms of individual development. Thus for Vygotsky, in the tradition of Marx and Engels, the mechanism of individual development is rooted in society and culture. (Vygotsky, 1978, Introduction, p. 7)

Glick (1983) also highlighted the importance to American psychology of Vygotsky's process-oriented approach to evaluating mental capacity in Vygotsky's conception of ZPD testing. Vygotsky's (1978) focus on the social foundations of individual higher mental functioning is exemplified in the ZPD concept, which he defined as the distance between a child's "actual developmental level as determined by independent problem solving" and the higher level revealed in "potential development as determined through problem solving under adult guidance or in collaboration with more able peers" (p. 86). Vygotsky provided examples of children with equivalent independent problem solving who, when dynamically assessed, have different ZPDs, and he considers the level of potential development more relevant for instruction than the actual independent developmental level.

By the time of a widely read Rogoff and Wertsch (1984) volume on *Children's Learning in the "Zone of Proximal Development"* (also see Wertsch, 1978, who cited Wood et al., 1976), the ZPD was becoming a fundamental component of the learning and education research literature.[1] Inspired not only by Vygotsky but work in a similar vein by the clinical psychologist Reuven Feuerstein,[2] Ann Brown and colleagues (e.g., Brown & Ferrara, 1985; Campione, 1989; Campione & Brown, 1984, 1990; Campione, Brown, Ferrara, & Bryant, 1984; for their connections with Michael Cole's "Laboratory for Comparative Human Cognition," see Cole & Griffin, 1983) were working on what they called "dynamic assessment" in which a cascading sequence of hints was provided to enable a dynamic assessment of how much support a learner needed to complete various benchmark tasks.

A preeminent example of work in this era was Scardamalia and Bereiter's (1983, 1985) research using what they have called "procedural facilitation" as a pedagogical technique to support the use of more advanced writing strategies (also see Applebee & Langer, 1983, on "instructional scaffolding" for reading and writing). Procedural facilitators were at first physical note cards with lead-in components to sentences that were designed to provide structuring devices to scaffold the young writer's writing activities and as such were explicit models of more advanced forms of writing. There was no question in this work that the procedural facilitators were intended to be but a temporary adjunct in the writing process. Pea and Kurland (1987) reviewed the state of the art at this period in bringing together developmental understanding of the writing process with the new computer writing tools of adults and industry toward what they called "developmental writing environments" that would directly facilitate the development of writing skills and

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[1]As reported in Gindis (1997), Educational Resource Information Center (managed by the U.S. Department of Education) records revealed three times more references to Vygotskian research in education than Piagetian research.

[2]Reuven Feuerstein is a clinical psychologist who studied with Jean Piaget and has for years been Education Professor at Israel's Bar Ilan University. Feuerstein's inspiring work on the social and cultural conditions for modifiable intelligence was rooted in his experiences in the 1940s as codirector and teacher in the School for Disadvantaged and Disturbed Children in Bucharest and his work with child survivors of concentration camps. Feuerstein's theory of structural cognitive modifiability and the Feuerstein method, which he calls "instrumental enrichment" involves emergent practices of dynamic assessment in which he places so called retarded children and adults (many with Down's syndrome) with often dramatic learning results in what he calls "shaping environments" that provide structured mediation to enrich the quality of their interactions with others such as parents, teachers, caregivers, and peers so that their experiences can be grasped and integrated meaningfully (e.g., Feuerstein, Hoffman, Rand, & Miller, 1980; Feuerstein, Rand, & Hoffman, 1979; also see Kozulin & Rand, 2000; Lidz, 1987). For more recent work on dynamic assessment, see Pellegrino, Chudowsky, and Glaser (2001).

not only be useful for text production (see Pea, 1987, for a related analysis of cognitive technologies for mathematics learning). Inspired by these efforts, Hawkins and Pea (1987) developed the INQUIRE software system for inquiry process supports in bridging children's everyday and scientific thinking with modules such as Questions, Notes, Schemes, and Patterns.

I believe that the seeds for the diffusion of the concept of scaffolding are already latent in Vygotsky's (1962) influential writings, for unlike the child language and play work from Bruner, Wood, and others in which the concept was developed as a prospective mechanism of human development in naturally occurring activities and not designed or technologically mediated ones, Vygotsky's conceptions of human development brought together the informal and the formal, the natural and the designed, to achieve his theoretical ends. For in Vygotsky's (1962, 1978) view, even the naturally occurring interactions in which the mother scaffolds the baby were culturally constituted productions with a history that made them akin in kind to the more historically recent instructional interventions in formal education by which we seek to teach a scientific view of concepts. So scaffolding was destined to become a concept, fueled with a Vygotskian (1978) sociohistorical view of development, which is applied so broadly as to encompass features of computer software (e.g., Tikhomirov, 1981; Pea, 1985a, 1985b), curriculum structures, conversational devices such questions, and physically literal examples of scaffolding the learning of a complex motor activity like tennis (in which one may physically assist the novice tennis player, helping position the body, arm, and racket to facilitate a sense of making a first racket stroke). Nonetheless, there are noteworthy differences between the ongoing cultural practices of a community in which informal scaffolding takes place in adult–child interaction patterns and the scaffolding incorporated in formalized activities within systems of designed books, software, materials for learning and other artifacts crafted specifically to promote learning activities.

I believe that we have two primary axes for organizing the theoretical contributions to supports for the processes of learning. One axis is *social* and most concerned with interactive responsiveness that is contingent on the needs of the learner, providing resources that enable the learner to do more than he or she would alone. The other axis is *technological* and about designed artifacts, written about so articulately in Herbert Simon's (1969) *The Sciences of the Artificial.*

For many of the contributions to the theory and research on human development, learning, and education, these two axes may be more or less dominant in their conceptualizations. For early language and conceptual development, I argue that the social conception of between-people scaffolding and support for learning is not primarily about the uses of technological artifacts but about social practices that have arisen over millennia in parenting and other forms of caring.

More recently, as computer tools have become increasingly used for supporting learning and educational processes in school and beyond, the concept of scaffolding has been more commonly employed to describe what features of computer tools and the processes employing them are doing for learning.

The theoretical challenge is that for humankind, tools and symbolizing technologies (such as written language and number systems) are among our most significant cultural achievements and, as such, they have become part of the cultural resources that we utilize to propagate society across generations, providing significant value-added to the social processes of between-people support and caring in the learning process. Also, in online learning environments that are mediated by computer technologies and computer-based versions of symbolizing technologies for representing linguistic, mathematical, scientific, and other concepts and relationships—but nonetheless incorporating between-people support components—the ways in which scaffolding is made possible are extraordinarily diverse.

These two threads of social process and tool/mediating process in the scaffolding concept came together most noticeably for Western conceptualizations of learning and education through the translated writings of Vygotsky in *Thought and Language* (1962) and *Mind in Society* (1978). Perhaps as Bruner wrote the Introduction to *Thought and Language* for publication in 1962, his first encounters with Vygotsky's considerations in these newly translated writings came to play a seminal role in his later work with Wood and Ross and in language development as well. Vygotsky's concerns were also carried forward in the work of his students Luria (Cole, 1978) and Leon'tiev (1981) and in activity theory since that time (e.g., Engeström, 1987; Engeström, Miettinen, & Punamaki, 1999) as well as cultural psychology more broadly (Cole, 1996).

FRAMEWORK FOR THE DEFINITION OF SCAFFOLDING

Like several of the authors in this special issue, I find it productive to return to the discussions of scaffolding in Wood et al. (1976) and to consider current work on scaffolding in this light. There are several components to this definition, which I call here the *what, why,* and *how* of scaffolding. The what and why of scaffolding may be considered together, and the how of scaffolding can be taken separately.

First, as to the WHAT and the WHY of scaffolding: Scaffolding situations are those in which the learner gets assistance or support to perform a task beyond his or her own reach if pursued independently when "unassisted" (Wood et al., 1976, p. 90). Right away, one can see how fundamental aspects of this founding sense of the term differ from the work reported in the four articles in this issue. In the scaffolding activities of the adult when working with the child in the Wood et al. study, there is a diagnosis of the learner's proficiency and an adaptive level of support that is provided by the adult, with the temporal dynamics of the scaffolding process implying cycles of comparison between the assessed level of performance the learner is exemplifying at any moment in time and the level of scaffolding that is responsively provided and with the dynamic of the process proceeding through such dynamic assessment cycles toward the learner's autonomous performance. Stone (1993, 1998a, 1998b) has also highlighted the dynamic nature of the scaffolding process dependent on cycles of assessment and adaptive support. A fundamental aspect of the scaffolding process was thus considered to be what only later came to be called "fading" of the scaffold, to use the term that I believe was introduced in Collins, Brown, and Newman (1989) and used by many others since:

> Once the learner has a grasp of the target skill, the master reduces (or fades) his participation, providing only limited hints, refinements, and feedback to the learner, who practices successively approximating smooth execution of the whole skill. (p. 456)

Such fading, I argue, is an intrinsic component of the scaffolding framework: Without such a dismantling mechanism, the kinds of behaviors and supports that have been more recently described as scaffolding actually reflect the much more pervasive form of cognitive support that enables what some call "distributed cognition" (e.g., Hutchins, 1995) and what I have called "distributed intelligence" (Pea, 1993, 2002).

From this perspective, the main sense of distributed intelligence emerges from the image of people in action whose activity is enabled by the configuring of distributed intelligence. However, that intelligence is distributed across people, environments including designed artifacts, and situations. This is in contrast to intelligence viewed as a possession of the individual embodied mind. I thus describe intelligence as accomplished rather than possessed. As I (Pea, 1993) noted in my chapter on distributed intelligence and education

> 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 to 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 of 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. (p. 50)

I believe that clearly delineating the boundaries between scaffolding with fading and more general distributed intelligence without fading is a central problem for the learning sciences and for education, and the argument structures and warrants used in marking these boundaries will be informative—as well as contentious. So many new forms of human activity that involve computing would be simply unachievable without the computing supports enabling the acts of distributed intelligence. Fading is simply out of the question. People cannot do the activities without the technologies, or it becomes meaningless to ask whether they can do so.

If the support does not fade, then one should consider the activity to be distributed intelligence, not scaffolded achievement. I return to this core issue later on.

Second, as to the HOW of scaffolding, the Wood et al. (1976) article was especially useful in defining several of the properties for how such assistance functioned for the learner. These properties fell into two primary groups, with shorthand names I use for them (not used by Wood et al.):

1. Channeling and focusing: Reducing the degrees of freedom for the task at hand by providing constraints that increase the likelihood of the learner's effective action; recruiting and focusing attention of the learner by marking relevant task features (in what is otherwise a complex stimulus field), with the result of maintaining directedness of the learner's activity toward task achievement.
2. Modeling: Modeling more advanced solutions to the task.

Although channeling and focusing appear to be closely related, they may be distinguished in the following way: Whereas the scaffolding process of channeling reduces the degrees of freedom for the task at hand, there is nonetheless the potential for the learner not to be focusing on the desired task component or property in a temporal sequence of task-related behaviors. So the scaffolding process of focusing is a more restrictive, limiting aspect of scaffolding.

CRITICAL CONSIDERATION OF THE ARTICLES IN THIS SPECIAL ISSUE

In the remainder of my commentary, I reflect on the issues raised in the four articles in terms of the scaffolding concept and its relation to distributed intelligence and raise questions that I feel warrant continued attention toward making advances concerning this central concept in the learning sciences and instructional theory.

The WHAT and WHY of Scaffolding

It is significant that the dynamic assessment intrinsic to the scaffolding framework that I have outlined, which was integral to the original Wood et al. (1976) definition of the term, is absent in the software systems that are described in the articles in this issue as is acknowledged by the authors, for example, Reiser (this issue): "The sense in which tools can scaffold learners under such conditions are clearly quite different than expert teachers who can tailor their advice to an assessment of the individual learner state" (p. 298). Thus, the microgenesis of scaffolding processes evident in the problem-solving support by the adult as the child works on the pyramid puzzle or in the peekaboo games characterized by Bruner and Sherwood

(1976) or Cazden (1979) is not an ingredient to the presumed scaffolding of these software systems.

The reasons for this absence are apparent and noted by authors such as Reiser (this issue): Our field simply does not have the design knowledge as yet for how to provide diagnostic assessment that is responsive to what the learner needs for such complex cognitive tasks as the conduct of scientific inquiry. Intelligent tutoring systems for procedural domains such as algebra problem solving or geometric proof, by contrast, do seek to reason about the states of individual learners and provide next-step, responsive support. Reiser (this issue) thus observes how "the approach in the scaffolded cognitive tools has been to embed support within the system as prompts or represented in the structure of the tool itself," leaving adaptation "under the control of the learners who can explore additional prompts or assistance available [or] attempt to follow or work around the system's advice" (p. 298). The scaffolding need in this case might even be called metascaffolding: If the learner does not know how to structure their problem-solving process for productive inquiry, how is it that they are expected to know how to decide among nonadaptive choices for scaffolding? They need scaffolds for the scaffolds. This may be a useful locus of teacher support in what Tabak (this issue) in her article calls "synergistic scaffolding" when students are using such software.

Nonetheless, Reiser's (this issue) effort to distinguish what he calls the "structuring" and "problematizing" aspects of scaffolding bears closer scrutiny on the issue of adaptive support vital to the scaffolding definition. Reiser seeks to explain by what "mechanisms" a software tool provides scaffolding for learners and what model will account for how the tool has benefited learners. Reiser (this issue) differentiates two such mechanisms: *task structuring* ("guiding learners through key components and supporting their planning and performance" [p. 273]) and *content problematizing* ("tools can shape students' performance and understanding of the task in terms of key disciplinary content and strategies and thus problematize this important content" [p. 273]).

Reiser's (this issue) goal is to make the problematizing mechanism of scaffolding a more central issue for our attention in scaffolding theory and design, and this is quite significant, as it could lead to productive uses for the scaffolding concept in instructional activity design. Reiser distinguishes structuring tasks to make them more tractable from shaping tasks for learners to make their problem solving more productive. I found this distinction hard to maintain as I worked through reviewing either the software systems he describes or those of the other articles. For example, the same tool features may both simplify and problematize by focusing learners on task components that they have not yet accomplished. Reiser (this issue) defines a broad array of characteristics that he believes create problematizing conditions for scaffolding including directing attention of the student toward an issue that "needs resolution," a triggering of affective components such as "creating interest" in advancing understanding, establishing a sense of "dissonance or curiosity," and more generally, "engaging students." In the end, I started to see that I could identify examples of task simplification without problematization, and so I grant that any existence proof for the value of the distinction Reiser wants to make provides warrant for his distinction. Yet it remains an open empirical question under what conditions it is that a specific scaffolding feature and affiliated scaffolding process work to problematize tasks for any given learner depending on the nature of the tasks; the learner's background knowledge, capabilities, and interests; and the social context. As Reiser (this issue) notes, "the social context of collaborative problem solving is often integral to the problematizing nature of the tool" (p. 289), which suggests that the problematizing brought about by scaffolding is less a mechanism in the tool than a social function of its interpretation in the particulars of the discourse of a learning situation.

I also was not sure what Reiser (this issue) meant by mechanism. For physical tools, a *mechanism* is a method, procedure, or process involved in how something works. For learning, one is familiar with proposed mechanisms of learning, such as assimilation–accommodation (Piaget, 1952) or knowledge compilation (Anderson, 1983). However, I found the hybrid use of the term confusing, as it is used interpretively to mark what Reiser as theorist believes to be what is happening for the learner as the software scaffolding features are used in the conduct of a complex task of inquiry. So it is neither about a descriptive feature for a physical tool nor a proposal about an internal mechanism for learning but a hypothetical characterization concerning how (external) scaffolds work for (internal) learning. When mechanism is used in this way, it is important to ask what will count as evidence for claims concerning how scaffolds work.

Reiser (this issue) provides illustrative examples of problematizing student work in characterizing how, as students interact with high school biology scaffolding tools and create artifacts, they are constrained to using important epistemic features of the discipline embodied in software menu choices: "Rather than just writing down their explanation, the tool forces them to consider how to express their hypothesis and its support within a disciplinary framework such as natural selection" (p. 291). Even with examples of student discourse when using this software, I could still not determine what data counts as evidence in support of a claim for any given instance that a particular feature of a scaffolded cognitive tool functioned to scaffold learning in terms of one, the other, or both of these two proposed mechanisms. However, the distinction has promise and can be developed in its empirical grounding in future work.

The Sherin et al. article in this issue also usefully foregrounds the need for the comparative analysis intrinsic to the scaffolding process definition in Wood et al. (1976). Perhaps because the call for papers requested conceptual work rather than empirical studies, Sherin et al. (this issue) do not provide any empirical data on this count except for their occasional reference to comparisons of the "hypothetical behavior of learners with and without the innovation" (p. 398). A challenge for the learning sciences to work on what kinds of data and analyses will help us better understand the role of scaffolding processes using software tools toward the targeted autonomous performances.

The HOW of Scaffolding: Channeling and Focusing, Modeling

Channeling and focusing in the articles. The articles offer many examples that illustrate the channeling function of scaffolding learner activities including systems dynamics model-building task decomposition in Model-It™, inquiry process scaffolding using Knowledge Integration Environment or Progress Portfolio, planning notations, progress maps, and constrained epistemic forms such as "what I know" and "high level question" in Computer-Supported Intentional Learning Environments. Reducing task complexity is a function of many of the categories of scaffolding defined by Quintana et al. (this issue) such as process management guides for mapping complex stages in an inquiry process with reminders and guidance toward progress and task completion. Reiser (this issue) also describes how some tool components automate the execution of some of the task components. Many of the software features described in the articles also focus a learner's attention by marking relevant task features to maintain directedness of their activity toward task achievement.

I found the category system comprising seven scaffolding guidelines and 20 scaffolding strategies in Quintana et al.'s (this issue) article quite interesting and an impressive formulation of an exceptionally complex field of software systems and their uses for science instruction and other areas of learning. As one point of methodology, it would seem important to develop interrater reliability data on classifying software systems or specific instructional practices in terms of these guidelines and strategies. As with any classification, even one done with the merits of a combination of top-down and bottom-up analysis such as this one, only time will tell whether these categories (forms of scaffolding) merit distinction as their uses are put to the test in design, analytic, and empirical work. What looks good as a theoretical distinction may be moot—or not—for the learning that results from its deployment in specific subject matter domains and implementation situations (e.g., depending on the teacher's roles, learning in groups rather than individually, student backgrounds and interests, etc.).

Reiser (this issue) describes how both features of the software tools and the artifacts produced by students in using them reveal the problematizing mechanism of scaffolding insofar as the tools students use to access, analyze, and manipulate data are structured so that the implicit strategies of the discipline are visible to students and in that the work products created by students are designed so as to represent important conceptual properties of explanations in the discipline (these features reflect scaffolding Strategy 2b and scaffolding Guideline 2 in Quintana et al., this issue). Reiser (this issue) characterizes these issues in terms of the Galápagos Finches software, which enables learners "to investigate changes in populations of plants and animals in an ecosystem and serves as a platform for learning principles of ecosystems and natural selection" (p. 286). The software scaffolds embody two different strategies for examining ecosystem data: through time longitudinally or cross-sectionally (by some dimension such as male–female, young–adult). The empirical question one may ask is whether the forced choice of strategies in using such templates to produce the students' artifacts yields continued uses of the strategies and expressions of the discipline's strategies in artifacts once the student is no longer using the tool.

Thus, the general issue with which I am concerned is whether students using a constrained set of forms for producing the work artifacts of scaffolded scientific inquiries are "parroting" back disciplinary forms of thinking rather than performing with understanding of what they have created (like the horse Clever Hans was doing when he seemed to be counting and doing arithmetic but was being scaffolded by subtle cues from his owner; Pfungst, 1911). It remains an empirical issue whether Reiser's (this issue) having "tools force them into decisions or commitments required to use the vocabulary and machinery of the interface" results in learners who attend to such structural features of knowledge and inquiry strategies in the science domain without such scaffolding around. Another software system called Animal Landlord distinguishes "observations" from "interpretations" (a preferred scientific practice and epistemic distinction) as students look at animal behavior videos, and the artifacts that they produce require use of this distinction. Once they have used this system, what is known about whether students are more likely offline to spontaneously differentiate observations from interpretations in their uses of scientific inquiry strategies and distinctions?

Modeling in the articles. There are numerous scaffolds described by the authors in this issue that seek to establish in both inquiry process and product artifacts a model for more developmentally mature scientific inquiry forms of activity. I see two issues of concern here. My first issue is where is the data in support of the model attribution for expertise? The second issue is the difference between a "model-without-a-person" and a scaffolding "person-as-a-model."

On the first issue, all of the articles but perhaps most clearly Quintana et al.'s (this issue) talk about the "target practices" of "expert knowledge" toward which they hope their scaffolding software features and processes will guide the student as learner (also see Sherin et al.'s, this issue, "idealized target performance"). In the characterizations of the science inquiry goal states for learners, where do these attributions of expert knowledge come from? From what I can tell, much of it is built from rational reconstructions and prototypical idealizations of inquiry (e.g., Krajcik, Berger, & Czerniak, 2002) and laboratory studies (e.g., Klahr, 2000), not social practice studies or cognitive ethnographic studies of actual mature scientific practices. Such empirical work in this vein, identified with work in the field of "science studies" (e.g., Bowker & Star, 1999; Galison, 1987, 1997; Knorr-Cetina, 1999; Latour & Woolgar, 1979/1986; Nersessian, 2004; Ochs & Jacoby, 1997; Rheinberger, 1997; Star, 1989), both challenge existing idealizations of science practice on which the scaffolding models are based and introduce new forms of scientific expertise that such idealizations rarely include (e.g., distributed reasoning; see Dunbar, 1999). These issues of empirically grounding the target state for learning in empirical studies of scientists are significant ones and warrant one's attention to the science studies literature and the increasing focus on technology-mediated practices in scientific inquiry. To take but one case in point, extensive research defining "novice–expert differences" reasoning and task performance in science was used to inform pedagogy (Chi, Glaser, & Farr, 1988), but it did not sufficiently heed the adaptive expertise of the mature practitioner in contrast to routine expertise (Hatano & Oura, 2003).

On the second issue concerning modeling, note that because the scaffolding provided in the software systems characterized in these articles lacks human agency for the learner to interact with, they may be missing what could come to be a key property of such modeling—a socially interactive other. One should consider the likely importance in scaffolding processes of a model in the sense of a role model, someone whose performances and knowledge one could personally aspire to as a cultural issue and involving at its core a sense of identity, an affiliation with that person and their values, language, and activity components as a part of a community of practice (e.g., Holland, Lachicotte, Skinner, & Cain, 1998; Holland & Lave, 2001, Lave & Wenger, 1991). Having such a model may have very different consequences for learning than working within a nonhuman model structure of a task model that has been developed as a generic pattern prompter for scientific inquiry.

Reiser (this issue) acknowledges as important but does not treat empirically in his article how the teachers' interpretive and discourse practices, among other properties of the classroom system, are essential to achieving the desired educational results from uses of the scaffolded cognitive tools. It would be good to see references to such empirical work on such practices and how they contribute to the benefits that software scaffolding may provide. Tabak (this issue) provides fertile examples of what she calls "synergistic scaffolding," an organization that brings together software features designed for scaffolding and teacher's scaffolding activities. However, this concept is not developed in terms of what properties of their interactions make such synergies work—or not. Such analyses would comparatively examine whether both software and teacher scaffolding functions could be achieved by software alone, by teacher alone, and what this says about whether it is important that the teacher's support is human and socially interactive or simply that it needs to be interactive and adaptive in nature (as software may eventually enable).

Fading in the articles. I am struck with the absence of reference to empirical accounts of fading or transfer in any of the articles in this issue, including the Quintana et al. article, which seeks to be synoptic in its scope, covering dozens of systems in use in the field. Are there known results from measured diagnosis of unaided performance and different forms of scaffolding provided (as required in the comparative definition of scaffolding and in its original formulations)? Are there theory-informed efforts to fade such presumed scaffolds during the course of their uses for the learners? What are the known empirical results from learners' uses of scaffolds and their fading over time as unaided performance becomes possible?

I am concerned that the reason for such silence is that many of the software features in the systems described appear to function not as scaffolds-with-fading but as scaffolds-for-performance in a way that will require them to continue to be used by the learners to be able to have them deliver the performances that are desired. Thus, there is distributed intelligence, not scaffold-with-fading. Some of these scaffolding designs, such as the Quintana et al. (this issue) category of "process management supports," look like they could be useful for the adult practicing scientist, too; others in sense making may or may not be useful to the scientist, but where there is overt embedding of scientific disciplinary strategies in the tool menus it certainly calls out for learning data from scaffold-with-fading to avoid the Clever Hans interpretation of student performances in using these tools. Of course, scaffolding-with-fading can be useful for adult learning, too, but I think that many of the supports described in these categories would function usefully as aides to the distributed intelligence achieved in the activities of adults or children without such fading.

However, the surprise is in the Sherin et al. article (this issue) on this point: Sherin et al. argue with the assumption in the original Wood et al. (1976) article on scaffolding that fading is a required component of the definition. Yet understanding the dynamics of scaffolding processes, including the selection and calibration of scaffolding structures during interactions, lies at the heart of developmental theory and the science of learning and roles that scaffolding plays in them. Although Sherin et al. have made good progress in helping us analyze scaffolding, they must now move forward to make headway on the issue of change over time. To not take on this issue is self-defeating and only a statement of the current limited state of the art that, as Sherin et al. (this issue) note, "in the case of technological artifacts, there is less of an opportunity for interactive tuning of scaffolding" (p. 403). In fact, it is not at all obvious that Sherin et al.'s framework cannot be applied to changes over time, and in the closing sections of their article, they even suggest that it can be so extended.

Relation of Scaffolding With Fading to Distributed Intelligence More Generally

In this section, I consider how scaffolding with fading as one of its integral components relates to distributed intelligence more generally. As Stone (1998b) highlighted and Tabak (this issue) highlights, scaffolding is not at all a theoretically neutral term. It is rooted in ZPD conceptions of learning and development and activity theoretic conceptualizations of the relations among people, tools, and environment. It is activity and performance centered (e.g., Engeström, 1987; Leont'iev, 1981; Vygotsky, 1978; Wertsch, 1991), not cognitive structure or task analysis centered to point to a very different theoretical tradition in cognitive science (e.g., Anderson, 1983; Newell, 1990).

Tabak's article (this issue) provides a rich discussion of how scaffolding relates more broadly to mediation of activity with cultural tools such as mathematical representational systems for place value multiplication and how this helps problematize, in interesting ways, the boundaries between (a) scaffolding considered in the context of instructional design and learning support and (b) distributed cognition more generally, which is commonly mediated by cultural tools and scaffolds created by others or by oneself as designs for achieving activities that would be error prone, challenging, or impossible otherwise.

If one considered scaffolding activity to be assisting performance generally, it would problematically span an exceptional range of human behaviors that includes adults, not only children, and many activities that people do not consider learning such as walking up stairs, sitting in chairs, flying in planes—each of which is assisted performance that would not be possible if unaided (stairs provide a physical scaffold for achieving greater height in a building, chairs provide a scaffold for activity in an intermediate state between standing and lying down, planes provide a scaffold for rapid travel avoiding those pesky mountains, etc.). Learning to scale heights without stairs, compose a sitting position without a chair, and unaided fast motion in the air are not goals of these scaffolds, and no one expects fading to be an integral part of the use of stairs, chairs, and planes as scaffolds. Closer to the examples of these articles on inquiry are the computer-supported activities of adult scientists using advanced scientific visualizations for reasoning about qualitative and quantitative relations about physical variables as in global warming, or making inferences about statistical relations in census data (without the revolutionary advances in exploratory statistical data analysis methods and software pioneered by Tukey, 1977), or longitudinal data modeling (using computationally intensive analytic methods; e.g., Singer & Willet, 2003). Insofar as I am aware, we are not asking adults using these methods to function autonomously without such tools.

Although certainly not the first,[3] one of the most significant formulations of the uses of computing to enable people to do what they could not do at all or could only do poorly without computing is in the seminal technical report on "augmenting the human intellect" written by Douglas Engelbart (1962, 1963) shortly before he and his group developed the first personal computer at Stanford Research Institute (SRI; Bardini, 2000; Hafner & Lyon, 1996; Waldrop, 2002). Engelbart (1962) wrote the following:

> It has been jokingly suggested several times during the course of this study that what we are seeking is an "intelligence amplifier." ... At first this term was rejected on the grounds that in our view one's only hope was to make a better match between existing human intelligence and the problems to be tackled, rather than in making man more intelligent. But ... this term does seem applicable to our objective. Accepting the term "intelligence amplification" does not imply any attempt to increase native human intelligence. *The term "intelligence amplification" seems applicable to our goal of augmenting the human intellect in that the entity to be produced will exhibit more of what can be called intelligence than an unaided human could* [italics added]; we will have amplified the intelligence of the human by organizing his intellectual capabilities into higher levels of synergistic structuring. What possesses the amplified intelligence is the resulting H–LAM/T system [*H*uman using *L*anguage, *A*rtefacts, and *M*ethodology in which he is *T*rained; italics added], in which the LAM/T augmentation means represent the amplifier of the human's intelligence. In amplifying our intelligence, we are applying the principle of synergistic structuring that was followed by natural evolution in developing the basic human capabilities. What we have done in the development of our augmentation means is to construct a superstructure that is a synthetic extension of the natural structure upon which it is built. In a very real sense, as represented by the steady evolution of our augmentation means, the development of "artificial intelligence" has been going on for centuries. (p. 19)

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[3]See Vannevar Bush's astounding 1945 essay "As We May Think"(Bush, 1945a), imagining the future of computers as "memex" machines that would support human activities from scientific discovery to business decision making using associative indexing [which came to be called hypertext]: For example

> Consider a future device for individual use, which is a sort of mechanized private file and library. It needs a name ... "memex" will do. A memex is a device in which an individual stores all his books, records, and communications, and which is mechanized so that it may be consulted with exceeding speed and flexibility. It is an enlarged intimate supplement to his memory. ... Wholly new forms of encyclopedias will appear, ready made with a mesh of associative trails running through them, ready to be dropped into the memex and there amplified. The lawyer has at his touch the associated opinions and decisions of his whole experience, and of the experience of friends and authorities. The patent attorney has on call the millions of issued patents, with familiar trails to every point of his client's interest. The physician, puzzled by a patient's reactions, strikes the trail established in studying an earlier similar case, and runs rapidly through analogous case histories, with side references to the classics for the pertinent anatomy and histology. The chemist, struggling with the synthesis of an organic compound, has all the chemical literature before him in his laboratory, with trails following the analogies of compounds, and side trails to their physical and chemical behavior. (p. 106)

Bush was the first Presidential Science Advisor whose strategic and futuristic thinking also directly led to Congressional authorization for the National Science Foundation (Bush, 1945b). Engelbart was very inspired by Bush's vision in his inventions.

In Doug Engelbart's (1962) remarkable report creating a new framework for thinking not only about computing but its relation to the history of human thinking and activity, he conjectured that computers represent a fourth stage in the evolution of human intellectual capabilities building on (a) the biologically based concept manipulation stage, (b) the speech and writing-based stage of symbol manipulation, and (c) the printing-based stage of manual external symbol manipulation, and now

> In this stage, symbols with which the human represents the concepts he is manipulating can be arranged before his eyes, moved, stored, recalled, operated upon according to extremely complex rules—all in very rapid response to a minimum amount of information supplied by the human, by means of special cooperative technological devices. In the limit of what we might now imagine, this could be a computer, with which we could communicate rapidly and easily, coupled to a three-dimensional color display within which it could construct extremely sophisticated images with the computer being able to execute a wide variety of processes on parts or all of these images in automatic response to human direction. The displays and processes could provide helpful services and could involve concepts not hitherto imagined (as the pregraphic thinker of stage 2 would be unable to predict the bar graph, the process of long division, or a card file system). (p. 25)

This tradition of using computers as what came to be called "cognitive technologies" at Xerox Palo Alto Research Center (PARC) in the 1970s and 1980s (see history in Rheingold, 1985/2000) was fueled significantly when the new center hired almost all of Engelbart's SRI group whose talents were then turned to creating the first commercially available personal computer, the Xerox Alto (Hiltzik, 2000). The interesting wrinkle in this history that then begins to connect up with developmental psychology and learning is that Alan Kay, the PARC impresario of portable personal computing with his vision of a Dynabook, brought the neo-Piagetian ideas and child-centered sensibilities of MIT professor Seymour Papert into the design of the PARC's cognitive technologies with his leadership of PARC's Learning Research Group. The development of bit-mapped computer screens, the SmallTalk object-oriented and message-passing programming language, constant pilot testing of PARC program user interfaces with children to see if they found them compelling and useful as "fantasy engines," and point-and-click interactivity were all part of the emergence of the art of human interface design at PARC in the early 1970s (Kay & Goldberg, 1977), and later the Macintosh team at Apple Computer took on this legacy (and significantly, some of its key staff).

Now consider—with tongue in cheek—a different spin on today's personal computer and its accessible user interfaces with this design history: Imagine an account of personal computing that was developed not by the likes of Kay but by educators who insisted on scaffolding-with-fading of the kinds of supports provided by the cognitive technologies that the computer afforded instead of integral use of computers in a coevolved pattern of activity in which the human and the machine roles in conducting complex inquiries and performing advanced scientific modeling and simulations needed to transfer to the learner, alone, working without the computer.

With distributed intelligence, the point is often not about fading at all, but being able to act in a context of assumptions of availability of tools—representational, material, and other people—for achieving ends. Educators, policymakers, and learners need to weigh the perceived risks affiliated with the loss of such support with the value of the incremental effort of learning how to do the task or activity unaided should such tools and supports ever become inaccessible, and the answer has to do with the social and technological assumptions humans make. As we approach a world in the coming years with pervasive computing with always-on Internet access, reliable quality of service networks, and sufficient levels of technological fluency, the context assumptions that help shape cultural values for distributed intelligence versus scaffolding with fading are changing.

So that is one of my concerns here. I believe the authors in these articles have been making significant progress in providing technological and pedagogical supports to the conduct of scientific inquiry in its bootstrapping phases. I see two large vistas of questions for the work ahead. First is the fascinating and challenging question of sorting out empirically which of the sense making, process management, and articulation and reflection supports that they and others have created should be conceived of as scaffolds-with-fading to be pulled down and whisked away once the learner is able to perform as expected without their use—and which of these supports deserve to serve in an ongoing way as part of a distributed intelligence scientific workbench and as fundamental aides to the doing of science whose fading is unnecessary and unproductive.

The second vista is engaged more with cultural values than with empiricism. For the most part (except Tabak and briefly, Reiser, this issue), the articles in this issue do not take on developments of any specific social practice in science inquiry whose performances are scaffolded (for contrast, see Hutchins, 1995, on navigation in relation to its instruments and social practices). Yet the issue looms large. If one can assume regular access to the scaffolding supports by the person using them, and if their use may accelerate broader access to the forms of reasoning that employ them (such as science inquiry), the question is pressing: Why fade? Tabak provides a historical consideration of scaffolding and its relation to distributed cognition, and Reiser hints at it. Sherin et al. (this issue) note that "it is not even clear that it makes intuitive sense to call the calculator a scaffold," as it has become so common that "if a calculator is a fixed component of mathematics problem-solving activity, can it still be called a scaffold?" (p. 390). Sherin et al. (this issue) go on to correctly observe how "the more that our learning artifacts transform the task, the harder it will be to understand how the learner might be 'doing the same thing'" (p. 395). So these value considerations in relation to issues of scaffolding as an educational concept are a vital need, particularly in terms of the historically changing relation between scaffolding-with-fading and distributed intelligence.

What Does It Mean to Test Scaffolding Theory?

It is important to begin testing the claims of scaffolding theory in which scaffolding theory involves specific formulations of what distinctive forms and processes of focusing, channeling, and modeling are integral to the development of expertise. It also appears that embodied within a theory of scaffolding needs to be a theory of transfer of learning for autonomous performance as well, or, more likely I would argue, a theory of scaffolding needs to be situated with respect to a theory of the development of the distributed intelligence, as learning to "work smart" (Bransford & Schwartz, 1999; Bransford et al., 1998) will often involve, as adaptive expertise, learning to establish one's own scaffolds for performance,[4] and fading these may be beside the point—fading of supports as a somewhat Puritanical concept that is inappropriate for modern times.

Among the considerations in such a formulation, it seems to me, would be the following:

1. A theory of scaffolding should successfully predict for any given learner and any given task what forms of support provided by what agent(s) and designed artifacts would suffice for enabling that learner to perform at a desirable level of proficiency on that task, which is known to be unachievable without such scaffolding. Thus, one needs independent evidence that the learner cannot do the task or goal unaided. One would imagine as a primary concern the need to take on issues of over what range of situations this determination would be made or inferred. This concern is also implied in the comparative formulation of scaffolding by Sherin et al. (this issue).

Such a theory of scaffolding would also need to account for recognition processes by which a learner recognizes a situation as an appropriate one for deploy-

[4]Teaching for the design of distributed intelligence ... would encourage and refine the natural tendency for people to continually re-create their own world as a scaffold to their activities. ... In mathematics and science education, one might develop a metacurriculum oriented to learning about the role of distributed intelligence in enabling complex thought. ... They would come to see through their activities where the bottlenecks of complex mentation reside. They would recognize how physical, symbolic, and social technologies may provide the supports to allow for reaching conceptual heights less attainable if attempted unaided. This goal might be achieved through examination of living, everyday examples (building from cases where they already do distributed intelligence in the world), and, perhaps, through case studies of the roles of information structures (e.g., matrices, flowcharts, templates) and social structures (work teams; apprenticeships) in mediating learning and reasoning as activity systems of distributed intelligence. (Pea, 1993, pp. 81–82)

ing the knowledge or skills in an autonomous manner that was developed through scaffolding.

2. In reading the articles, I was astonished to find that they do not distinguish learners at different developmental levels of knowledge or of distinctive beliefs about knowledge and learning (e.g., Hofer & Pintrich, 1997), even within science tasks or in terms of epistemological views on the nature of science—although extensive literature is available in science education that uses such developmental levels (e.g., Carey, Evans, Honda, Jay, & Unger, 1989; Halloun, 1997; Hammer, 1994; Kuhn, Amsel, & O'Loughlin, 1988; Linn & Songer, 1993; Redish, Steinberg, & Saul, 1998; Roth & Roychoudhury, 1994; Smith, Maclin, Houghton, & Hennessey, 2000; Songer & Linn, 1991). It would seem that scaffolding theory by its very nature needs to characterize a developmental trajectory for levels of performance on the tasks that it is designed to dynamically scaffold. The diagnoses and adaptive support that scaffolding as a process provides would move stepwise with the learner up the developmental level sequence until such mastery has been achieved that the fading has been accomplished.[5]

It seems possible to imagine "mixed initiative"[6] designs of scaffolding processes in which people and machines join together in helping someone learn something in the sense that certain scaffolding activities can be the responsibility of the teacher (or peers) and other scaffolding activities provided by the software. Even if the software cannot do an assessment of the learner and then provide adaptive scaffolding on its own, it seems entirely possible that the teacher could do such an assessment and then be in charge of switching levels of scaffolding that are provided by the software. In this way, a scaffolding partnership, or synergy, as Tabak would call it, could be achieved in support of the learner's advances. How these "divisions of labor" should be achieved is a theoretically fertile area for learning sciences research (e.g., Stevens, 2000).

3. Testing scaffolding theory for the purposes of informing instructional design has some distinctively different issues affiliated with it. The designer needs to know how to scaffold what facets of the scientific inquiry process when, and with what expected results, along a learning trajectory in which new answers will be given to what is needed. The complexity of the scientific inquiry process is such that it cannot all be scaffolded at once. (There are strong analogs here to the writing process and forms of scaffolding that have been provided for learning to write in-

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[5]Davis (2003a, 2003b) has provided an example of work that can inform the making of such connections in her studies of how students with different beliefs about science learning used and benefited from different types of scaffolding.

[6]Carbonell (1970) is most identified with the concept of mixed initiative systems for learning support. Carbonell created the first intelligent tutoring system, and its design was such that either a human teacher or the computer program could ask questions. Today, such mixed initiative systems are commonly provided in customer-relationship management and call centers, in complex planning, and more recently to aid information-seeking behavior.

cluding writer's workshops and various software tools.) Yet from reading these articles, the instructional designer does not have at hand any rules for making decisions about what kinds of scaffolds (among seven scaffolding guidelines and 20 scaffolding strategies in Quintana et al., this issue) to provide in what kind of adaptively relevant sequencing for advancing a learner's capabilities.

4. In the activities of scaffolding for learning, what specifically requires the social face-to-face of scaffolding versus the interactivity that might be provided by a software artifact? Is contingency of responding all that matters (e.g., Reeves & Nass, 1996; implied in most of these articles as well), or is it human agency that is crucial in the scaffolding process? It is entirely possible that issues of identity development, community or cultural values, a sense of belonging/affiliation, faith, trust, individual caring, and responsibility weigh into these matters and that without the "human touch" of scaffolding and fading from agents that truly represent these dimensions of experience, scaffolding and fading for learning may be less effective (or unhelpful altogether). Reminding a child of a rule to be followed in a game may provide both a metacognitive scaffolding prompt but also be emblematic of a caring response that motivates its consideration (e.g., Lepper & Woolverton, 2002). In this respect, it is somewhat worrisome that what is valued by people in the uses of these scaffolds is too distant and relatively invisible in the scaffolding artifacts that are developed and used by Reiser (this issue) and others in these articles. A learner cannot have a dialog with the scaffolding supports in an inquiry system such as the BGuILE ExplanationConstructor—like one could a person doing BGuILE-like interpersonal scaffolding in a classroom—about why one needs to answer a question in a certain way. Conveying the rationales for performing different scientific practices by means of a prescription built into a software scaffold, as recommended by scaffolding Strategy 5b in Quintina et al.'s article, may not have enough of a human touch.

CONCLUSION

Like the term *community* in learning theory and educational uses of phrases such as "community of practice," "community of learners," "online community of learning," it is important to note that theoretical issues are not settled by definitions per se (Barab, Kling, & Gray, 2004; Renninger & Shumar, 2002). Yet definitional issues and category systems of kinds of scaffolds and scaffolding occupy a large proportion of the pages in these articles. The vital question, ontologies aside, is this: What work does the concept of scaffolding do in theories of learning and instruction? How does the scaffolding concept, however articulated, stand in relation to the specific goals of explanation, prediction, and the coherence of theoretical claims for a theory of learning, encompassing learning in everyday cognition, work practices, and in formal education? How does the scaffolding concept stand in relation to its effective use in what Bruner (1966, 1996) has called a "theory of instruction" to guide the structure and sequencing of its instructional designs, its situated practices, and its outcomes? Reflecting on these questions, I recommend several new emphases (a) on establishing systematic empirical investigations of how the scaffolding process relates to learning and not only to performance and (b) in designing and researching uses of mixed-initiative systems that combine human help from teachers and peers with software system features that aid scaffolding processes.

One thing for sure: Scaffolds are not found in software but are functions of processes that relate people to performances in activity systems over time. The goals of scaffolding research going forward should be to study how scaffolding processes—whether achieved in part by the use of software features, human assistance, or other material supports—are best conceived in ways that illuminate the nature of learning as it is spontaneously structured outside formal education and as it can most richly inform instructional design and educational practices. In either case, to advance the prospects of learners, thickly textured empirical accounts are now needed of how scaffolding processes in such activity systems work in comparison to their independent performances, even when (and perhaps especially when) the results deviate from the best intentions of their designers. We need to see best practices (when scaffolding systems work as planned) but also the troubles that arise when learners turn out not to act in the ways that designers hoped and when addressing their needs can stretch our imaginations, theories, and designs. These articles have focused more on properties of software and curriculum for science inquiry than they have learner performances and transfer of learning considerations.

When software designed to scaffold complex learning is used, the burden of proof is on the researcher to (a) document how it is that it serves to advance a learner's performance beyond what they would have done working alone (i.e., the ZPD comparison needs to be warranted) and (2) what processes of fading need to be employed to sustain the learner's autonomous performance of the capabilities in question across transfer situations that matter. Such proof needs to be provided for each learner, not only selected learners or groups that serve to illustrate the best practices of scaffolding processes.

Finally, these articles provocatively call one's attention to the boundary issue between scaffolding defined with fading as a necessary condition and distributed intelligence in which scaffolded support enables more advanced performances than would be possible without such support but in which fading is not a cultural goal. Such boundary issues are at once empirical and normative as we debate values for what learners should be able to do with and without such designed scaffolds—debates nonetheless informed by empirical accounts of learners' performances in the diversity of situations in which their knowledge and adaptive expertise should come to play.

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