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ARTICLES

Intuitive Expertise and Empowerment: The Long-Term Impact of Simulation Training on Changing Accountabilities in a Biotech Firm

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This paper describes a two-year study in which high levels of performance were achieved and sustained among so-called low-level workers in a biotech company. The purpose of the study—funded by National Science Foundation and Invitrogen Corporation—were to explore the effectiveness of an accelerated learning Operational Simulation (OpSim) training on workers in biological manufacturing. While greater responsibility is demanded of "front-line" workers in biotech, efforts at "empowerment" have not worked well in this context. In this particular OpSim, workers were facing a large and expensive backorder problem. The OpSim did not target or specify the skills or means for greater responsiveness; rather we emphasized only goals and challenged the groups to develop a solution. All groups failed on the first try, but exceeded desired outcomes on the second try and subsequently sustained these performance objectives. Implications for Naturalistic Decision Making, training, and empowerment are discussed.

Increasingly, companies in rapidly changing markets rely on highly experienced but not highly educated "technicians" to support "high-end" work, particularly in fields like medical research, advanced manufacturing, or medical care. Many types of organizations are undergoing changes

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in which so-called lower level workers are being placed in capacities in which they must make "mission critical" decisions, which can have a substantial operational and/or financial impact. For example, in other work we and our colleagues have discussed how the influx of enterprise-level information technologies has placed more workers on a company's critical path. As information technologies continue to grow as a means of organizing operations, increasing numbers of frontline workers enter into the role of "knowledge workers" in that they must interpret constantly changing information or manipulate information that will change or impact the activities of others (DiBello & Glick, 1993). Highly connected technologies have not changed all workplaces equally, but the success of companies that are doing more with less has raised the bar for everyone and created expectations about what can be accomplished. This is true even when the frontline work still looks very much the same—that is, when there is no "advanced technology" changing what workers do—and the spotlight on frontline workers as knowledge workers cannot be turned off.

This shift forces organizations to reorganize the way they do business and, perhaps more important, the way they think about their work. As the basic requirements for frontline workers intensify, organizations need to figure out innovative ways to harness expertise and at the same time organize the workplace at the structural level to support outcomes in line with new demands. Furthermore, new accountabilities for frontline work have important implications for several areas of research, particularly literatures on expertise, empowerment, and organizational change.

Our purpose here is to examine the cognitive underpinnings of organizational performance in a real-world setting, focusing in particular on the ways in which structural interventions can most effectively reorganize and harness expertise among a workforce experiencing changing accountabilities. Extending the early work of Sylvia Scribner (1988) on the integration of thinking and doing in work tasks, we look at the ways in which workplace "cultures of practice" influence the ways that people view situations and make decisions (i.e., has a shaping impact on their working mental models) and conversely how these ways of thinking become a "default" mode that is highly resistant to change, even when the individuals who have them realize they are no longer adaptive. Our basic research has been the study of how individuals and groups shift to new cognitive frameworks or heuristic frames that are more appropriate to changing organizational goals. Sometimes the shift involves moving to a new level of expertise; sometimes an expert must make changes to his or her organizing framework. Our goal has been to understand the mechanisms that accelerate this shift to support desired outcomes.

Researchers have found that the inability to change thinking is responsible—in part—for the failure of many organizations to change their way of doing business as quickly as they need to in order to remain competitive or avoid failure. Yet, traditionally, cognitive science, both at a theoretical and methodological level, has viewed cognition as something that takes place "inside" the individual. As such, the discourse on organizational change operating within this perspective from top management gurus like Tom Peters and Jay Abraham, focus on top-down solutions, such as refocusing a company's "vision," reimagining business excellence, and implementing training sessions on effective leadership. In contrast, although we believe these are necessary components of organizational change, we view the basic mechanisms of cognitive reorganization in terms of "situational cognition," exploring both the individual and distributed systems of knowing and doing. These approaches view cognition as situated within an activity system, whereby individual cognition (and the organization itself as a thinking entity) is understood as inseparable from the developmental processes of cognition within the mediating structures of the task at hand (Hutchins, 1996). These mediating structures may include common workplace features like communication networks, promotion hierarchies, or the cultures of practice that become embedded in rules and procedures that define the organization's daily operations. This view invokes a "bottom-up" perspective in which the organization itself becomes the primary unit of analysis rather than just its leaders.

For this article, we describe a unique kind of accelerated learning simulation exercise conducted with a real biotech firm in a real crisis that serves as a "natural laboratory" for examining the complexities of cognitive reorganization and organizational change from this kind of bottom-up viewpoint. This aspect of our work is a method of aggressive intervention that has been instrumental in helping people "unlearn" and then relearn at a preconscious level. Broadly speaking, our interventions—called OpSims (standing for "operational simulations")—are a form of simulation-based training in which workers engage with a "reality analogous" version of their business environment in a compressed period. In doing so, participants confront organizational failures and rehearse strategic solutions while being held accountable to non-negotiable outcomes. The "vision" and "imagination" of what's possible in terms of organizational performance emerges from within rather than being engineered from the top. However, the nonnegotiable outcomes exert a top-down selective pressure on what develops cognitively. The approach has been used to help turn around poorly performing organizations by intervening at the level of intuitive decision making. Applied at both the high end and low end of the corporate ladder, this method has been instrumental in several successful turnaround situations. In one study, for example, management perceived frontline workers' resistance to information technology as an impediment to change and growth. We helped facilitate a successful information technology implementation and mobilize growth within the firm by using the OpSim intervention to reframe "resistance as an impediment" to change to "resistance as a catalyst" to change. Despite successes such as this, we still have a lot to learn about the underlying mechanisms involved in the strengths and weaknesses of our model.

The effectiveness and the underlying cognitive theory of OpSims are not the central topics of this article. Rather, for this study, we examine the effectiveness of the OpSim intervention for low-wage workers supporting high-end work, and we explore the implications of the study for issues of expertise, worker empowerment, and organizational change. Given this particular context of our study, we ask, How can we elicit and utilize expertise among frontline workers in the face of changing accountabilities? What kinds of structural interventions help align the implicit expertise in an organization with changing organizational goals? Finally, how can organizational change interventions support a long-term impact on expert performance?

As a part of adapting the OpSim methodology to the problems of this company, we reviewed other theoretical approaches that might inform our design. This work has been greatly influenced by work on literatures on intuitive expertise, organizational learning, and naturalistic decision making. We also believe this study has implications for literature on worker empowerment, which helps address the ways in which expertise manifests among various organizational structures. However, we have found that for our purposes, although all of these literatures provide insight into the basic processes and structures of organizations and decision making, they often do not explain the mechanisms behind how change occurs within the OpSim. In the end, we rely on Piaget's functional invariants and some features of Vygotsky's activity theory. We return to our uses of Piaget and Vygotsky after a literature review and description of the study.

INTUITIVE EXPERTISE AND ORGANIZATIONAL LEARNING

Most cognitive psychologists recognize that highly skilled people of all kinds—such as surgeons, pilots, physicists—over time become "intuitive experts." The notion of intuitive expertise involves a mastery over specific tasks that allows experts to tackle complex problems by acting on intuition without specific reliance on a set of rules, procedures, or guidelines. In the past, this model of intuitive expertise has been used to better understand expert performance and to better understand how decision making happens under stressful, high-stakes situations, without time for extensive planning or reliance on detailed information. These approaches contend that experts simply "know" the best course of action, relying on an implicit mental model, by which they can spontaneously assimilate their expertise into familiar problem situations. In familiar domains, intuitive expertise is quite powerful, enabling people to evaluate situations and act quickly without much reflection. Occasionally, however, a dominant framework undergoes revision. When the situation, goals, or organizing principles of a domain change, thinking guided by the implicit mental model still asserts itself—automatically—even though it may no longer be relevant or appropriate. Even knowing that we need to think differently does not help us do so. In this situation "experts" must develop a new framework for looking at the same issues as before. This can be a very painful and long process, and the old ways of looking at the problems can severely hinder the expert's ability to acquire a new framework for quite some time.

This line of research on expertise is complimented by research on organizational routines, heuristics, shared mental models, and causal schemata—cognitive phenomena that operate in every organizational environment but that can inhibit an organization's ability to effectively utilize its expertise and respond adaptively to changing environmental conditions (Levitt & March, 1988). Several lines of research reveal insight into the cognitive underpinnings of ineffective decision making in both inert and dynamic environments. Causal schemata, for example, represent "general conceptions of how certain kinds of causes can produce certain kinds of effects" (Oliver & Roos, 2005, p. 890). Causal schematas, combined with organizational "scripts," which provide coherence and meaning to particular decision-making patterns create an "interpretive scheme," form the basic cognitive model linking decisions and outcomes in the minds of organizational decision makers. This interpretive scheme has also been called a "heuristic," which "provides simplifications that limit the need for search in problem solving situations" (p. 901).

Organizational researchers generally agree that heuristics can negatively impact effective organizational decision making (Fiske & Taylor, 1991). Whereas heuristics can be beneficial insofar as they guide and organize decision making that occurs in often uncertain and high-pressure environments, they also create biases and can block adaptive thinking in dynamic and rapidly changing environments. In particular, they can create misperceptions of feedback that reinforce inappropriate interpretations of causal relationships among organizational processes. On the other hand, researchers also recognize that shared mental models based on adaptive models of organizational flexibility may enable effective decision making in dynamic environments.

The basic shared mental models of organizations frame the nature of the work carried out by expert decision makers. Thus a basic question concerning expertise and organizational change becomes, How do you change shared mental models based in organizational routines while retaining the implicit expertise of organizational members? One key model is unlearning, whereby organizational learning involves a destabilization of routines and shared mental models that are not aligned with the primary targets of the organization. The inability to forget routines may be a major hindrance to reaching a target. In addition, routines can get in the way of eliciting the intuitive expertise of organizational members.

A wealth of literature has explored implicit expertise, and we do not propose here that these ideas are original with us. Rather, our work has involved broadening this basic framework to all kinds of work among all levels. In all kinds of work, people develop optimized ways of working and analyzing situations as a function of the goals, tools, and resources in their working environments. We think much of this has been neglected. Further, we think the mechanisms of implicit knowledge or expertise in business situations and the ways it can inform theories of cognition have been especially neglected.

In our own research in workplaces and organizations, we have found that over time, frontline workers develop an intuitive expertise regarding the day-to-day operations and functions of particular task. We have found that this kind of expertise can be incredibly valuable to the success of complex organizations, particularly those whose frontline workers are accountable for "mission critical" tasks (e.g., medical care, biotech, transportation). Thus, although frontline workers in a biotech firm, for example, may not face the kind of life-and-death situations of firefighters or surgeons, they increasingly carry out "mission critical" tasks that must be highly adaptive to changing organizational conditions. The role of frontline workers in mission-critical decisions was first identified by Scribner (1988) in her now famous dairy studies, in which she studied the way in which situation-dependent frontline expertise led to greater efficiency in the organization of frontline tasks.

NATURALISTIC DECISION MAKING (NDM)

The field of NDM emerged to address the lack of relevance of classic decision-making models in dynamic, high-pressure environments. As such, NDM is characterized by a loosely defined set of heuristics and practices focusing on how people make decisions in real-world, real-time settings and perform cognitively complex functions in situations defined by "ill structured problems; uncertain, dynamic environments; shifting, ill-defined or competing goals; action/feedback loops; time stress and high stakes" (Gore, Banks, Millward, & Kyriakidou, 2006, p. 928). Whereas classic decision-making models emphasize logical deduction and rational analysis and often study decision making in laboratory settings with minimal contextual variables, NDM researchers began to notice that in the most critical environments, like emergency rescue scenarios, military combat operations, and disaster management, normative courses of action based on classical training models were rarely implemented. Perhaps more important, "experts" in these situations relied on a more intuitive, adaptive decision-making process as opposed to the analytic, deductive approach. The "recognition-primed decision" model, for example, outlined by contends that real-world experts confronting real-world problems (as opposed to novice participants in laboratory settings) make situation assessments to determine a likely course of action based on an intuitive process evolving from years of direct experience and engagement with a particular task environment.

The importance of intuitive expertise for critical decision making in dynamic environments creates a unique difficulty in job skills training, leading NDM researchers to address the problems of how to model expert decision making in these environments and refine training methods to reflect real-world, real-time processes.

> Given that, by definition, expert knowledge is domain specific and thus not necessarily transferable, it is critical to understand the more generic process of becoming "expert". The questions for NDM are then "How can this expertise be trained?" and "Can the learning required be accelerated or is it something that can only be acquired through experience?" (Gore et al., 2006, p. 935)

In general, the issue of training for the NDM literature is problematic, because for NDM researchers, there is a shift toward flexible, decentralized decision-making models that can adapt to dynamic organizational environments. This shift is somewhat incongruent with traditional training methods. Because training methods often assume that decision making is a rational, context-free process, they often assume that individuals can develop a generic analytic capability that applies across varying environments. As a result, training methods rely on predictable skills and generalizable results. Yet, although the NDM literature recognizes the need to address training issues in dynamic environments, it has been challenging to develop a consensus around adequate and effective models, in particular, because there is great variability both between and within typical NDM environments, which creates a lack of coherence and clarity around generalizable results.

In light of these difficulties, researchers within the NDM community have generated various training methodologies (Cannon-Bowers & Bell, 1997). Developing new training methods may not be possible without reexamining what we really mean by "training." "Effective training environments are systems that facilitate the ability of the participants to develop and maintain the competencies (i.e. knowledge, skills, attitudes) necessary to perform required tasks" (Oser, Gualtieri, Cannon-Bowers, & Salas, 1999, p. 443). However, effective training for required tasks in dynamic environments must involve more than simple instruction on job knowledge and content-based skills. In other words, because the content and context of particular tasks in dynamic environments is highly volatile, training is not a simple matter of relaying job knowledge or socializing newcomers, although these are necessary components. Rather, effective training in dynamic environments must address a different set of competencies, like adaptability, intuitive expertise, and "cognitive agility"—which is the ability to rapidly revise one's mental model in the face of changing feedback.

Although frontline workers are increasingly accountable for mission-critical decisions, many organizations do not have appropriate structures in place to adequately elicit their expertise. In many organizations, identifying the "experts" can be difficult. But part of that problem is that expert decision-making ability regarding certain tasks does not necessarily correspond to decision-making authority. It is our view that organizations that have strict hierarchical layers of decision making authority can actually disempower the very people who are most expert at making critical decisions, which ultimately hurts firms by miscalculating the best course of action.

Worker empowerment has been a subject of increasing debate over the past few decades, as both theoretical and empirical research accumulates regarding the specific meanings and definitions of workplace empowerment, as well as increasingly complex examinations of the relationship between empowerment and a number of key organizational performance-related outcomes. Research on empowerment typically examines the "strategies and tactics of resource allocation for increasing the power of less powerful parties and reducing the power of more powerful ones" (Conger & Kanungo, 1988, p. 472). These strategies have been collectively defined and examined as participative decision making (PDM). PDM has been defined as sharing influence and decision making among superiors and subordinates in a given organizational hierarchy. Advocates for this kind of empowerment approach argue that worker involvement is essential because "lower echelon employees often have the capacity to make better decisions than do their superiors regarding how their work is accomplished" (Spreitzer & Mishra, 1999, p. 156), and studies have shown positive impact of high employee involvement on employee morale and organizational effectiveness as well as task and job performance.

Despite some evidence of the effectiveness of PDM initiatives at the structural and individual level, many researchers have argued that participatory management programs are wonderful in theory but difficult and sometimes detrimental in practice.

> The simplicity and power of top-down, rule-based administration created competitive advantage in the past, but it blocks the responsiveness and continuous innovation that are the keys today. That is why "teamwork" and "empowerment" are seen almost everywhere as the road to success. But does it work? . . . The enormous efforts at restructuring are yielding for the most part disappointing results. To be sure, they usually produce some short-term cost reductions; but those who are looking for fundamental increases in organizational effectiveness aren't finding them. (Heckscher, 1995, p. 16)

Heckscher points to several sources of failure, primarily arguing that some participatory management programs mistakenly implement "participation" by simply setting up team-based production. Although teams may be key to effectively implementing participatory practices, they do not automatically help empower workers and can sometimes reinforce the negative communication barriers that hurt efficiency. In addition, for companies that used downsizing and reengineering practices and that have a history of layoffs, increasing participation was met with skepticism and caused undesirable "politics" within the workplace, as workers faced new responsibilities and requirements of organizational commitment that are contradicted by uncertainty and job insecurity.

Criticisms like Heckscher's led researchers to move away from a model of "empowerment only." As a response to some of the early failures in empowerment initiatives, one of the most recent and effective incarnations of worker empowerment initiatives, called high performance work systems (HPWS), draws together many elements of previous participatory management practices and responds uniquely to the current business and manufacturing climate, arguing that "the greatest gains in plant performance occur when plants adopt clusters of complementary practices" (Appelbaum, Bailey, Berg, & Kalleberg, 2000, p. 33). However, within HPWS, a central aspect is empowered decision-making capacity among traditionally disempowered, frontline workers. Many of the HPWS studies demonstrate that a well-designed HPWS can greatly enhance financial performance in for-profit corporations. Many examples have shown significant financial performance increases among firms employing HPWS in the automobile industry; the steel, apparel manufacturing, semiconductor, and oil refining industries; and service firms, as well as significant financial benefits in three major industries: steel, apparel, and medical instruments and imaging. Appelbaum et al. (2000) write:

> If tasks are uniform and stable, and if there are well-known solutions to problems that arise (for example, if workers can follow a short trouble shooting list to solve most likely problems), then a traditional, routinized, and centralized work organization is most effective. But if tasks vary frequently (perhaps from changing products or production technologies), then a more flexible, "polycentralized" organization is more appropriate. Put in terms we have used here, in the first case, little is gained from discretionary effort (except perhaps speed of work). In the second case, a work organization that makes use of workers' imagination and initiative is superior . . . . Increasing levels of uncertainty and change create powerful incentives for moving to flexible systems based on employee participation. (pp. 36–37)

A decentralized model of self-managed teams "rel[ies] on frontline employee skill and initiative to identify and resolve problems, to initiate changes in work methods, and to take responsibility for quality" (Pfeffer, 1998, p. 85). By allowing employees to make decisions without deferring to management and by providing the necessary training to help them make those decisions with confidence, organizations can enhance employee motivation to innovate, take initiative, and become more deeply involved in their work. In this sense, HPWS allow for emergent systems of decision making and sense making, rather than an imposed, standardized set of procedures.

Our work in the bio-manufacturing plant brought to light all of the issues just raised: the nature of frontline expertise and decision making, changing management hierarchies and accountabilities, and worker empowerment. As the organizational goals of the company shifted based on competitive pressures in a volatile business environment, the need for a cognition-based intervention became clear, as the old modes of organization thinking were no longer applicable to changing demands.

CHANGING ACCOUNTABILITIES IN A BIOTECH FIRM

Our site is a biological manufacturing company that makes proteins, bacteria, and other biological materials used for scientific research and drug testing. Their "brand promise" is to make scientific work faster and easier for scientists by eliminating steps in their process. Many of the products they make would have to be made by biologists working in labs as part of doing an experiment on something else. The idea is to make those routine steps into standard materials available for purchase. This process requires that they make labor intensive but necessary materials on a grand scale.

The company grew by acquiring literally scores of much smaller companies and their workers. Most of these start-ups comprised small teams of biologists who formulated unique products (such as proteins made by genetically engineered *e coli*), patented the process, and then manufactured the products in small batches. The acquisition strategy assumed that once a "recipe" is perfected, a technician who is not a biologist could be trained to follow the recipe and make the materials in larger batches. This would reduce costs, transform the material into a true product, and increase margins for the parent company while avoiding the time and money needed to formulate new recipes from scratch. More to the point, it would create a $3 billion business supplying scientists with material they need anyway. However, the collection of smaller companies under one roof brought in the informal small-group cultures and inefficiencies of the small labs. When we first conducted interviews at the company, we heard managers tell us, "We have about 25 small companies on one shop floor, and they are not working as one company." The net effect was a kind of scaling crisis that was inadvertently hidden by metrics normally used in large businesses. This led to a number of serious production problems that could not be nailed down.

A chief complaint from customers was the large number of back orders. A number of process improvement efforts and committees had failed to fix the issue, and the results of a number of in-house "studies" were not conclusive as to the cause or even the extent of the problem. During interviews with production employees, they uniformly believed this complaint was "overblown." They claimed that standard reports showed only about 2% of the products on back order at any given time. However, the company has about 5,000 products in their catalogue, of which 3,500 were active SKUs. Of those SKUs only 198 were 95% of the total orders. When looked at that way, the number of customer orders and revenue dollars tied up on back order approached anywhere from 40% to 80% at any given time. This amounted to as much as $800,000 worth of customer orders per day on back order. When confronted with these data, both workers and managers were surprised. They then defended the back order numbers by claiming the products are the result of biological processes that cannot, by their nature, have a firm deadline. "Sometimes the bugs don't grow and you have to wait or start over again." If this were in fact true, the company had a serious problem; the products were needed by scientists at critical points in their work; they could not wait for back orders and were forced to go elsewhere when the site could not supply them on time. When confronted with this fact, the staff next countered that the forecast itself was flawed. They explained to us that the company had a kind of retail business model, shipping things ordered from a Web site, often using overnight delivery. This model assumed that products ordered were in stock. The employees told us the forecast indicating what customers would buy was "always wrong" and this explained the high percentage of back orders.

When we drilled down into this situation, it was clear that the forecast was in fact relatively accurate, based on customer buying patterns and commitments from customers for future purchases. Why, then, was the back order problem so huge? When we compared the forecast to shop floor production, it was clear that the production personnel largely ignored the forecast, "cherry picking" work orders rather than making things to schedule. Workers made items they genuinely believed would be needed. They thought they were working around the inaccuracy of the forecast. In fact, they were contributing to back orders.

Most important, our research also revealed that some individuals manage to get the right number of "bugs" to grow to the right volume, on time, when necessary. The people who managed to pull off this miracle were usually not highly trained biologists and certainly not in the management ranks. We began to suspect that implicit expertise had developed through experience but that it was activated in response to crises, not business as usual. More to the point, this ability—however activated—demonstrated that it was possible to be on time when making and selling biological products on a large scale. The challenge was to solve a mission-critical problem in the business as a whole with the "help" of frontline workers who had developed the ability to accomplish the job only under crisis conditions.

THE OpSim METHODOLOGY

Among various training methods for experts working in complex, dynamic environments, one that has become widely cited by the NDM community is simulation-based training, often referred to as Event-Based Approaches to Training. Simulation-based or Event-Based Approaches to Training methods have been lauded for their ability to resolve several problems in training experts in dynamic environments, primarily, that simulation-based training allows for a participatory process, whereby expertise is not predetermined but rather is allowed to emerge from situational constraints.

> Simulations are ideally suited for training problem solving through exposure of teams to the types of environments and problems that may be confronted in a naturalistic setting . . . . Simulations can allow the instructional developer to manipulate and pre-specify the presentation of, and relationship between, critical environmental features. Within a simulated environment, it also is possible for the team to conduct problem solving in a realistic manner. (Oser et al., 1999, p. 443)

In addition, simulations can provide (a) a safe environment to practice making complex decisions in complex environments, with (b) multiple practice opportunities, and (c) opportunities for feedback that (d) may highlight specific patterns among individuals or teams and (e) can lead to the development of common goals.

However, one of the key elements of simulation-based training is that, although features of the simulated environment are manipulated by developers, the specific knowledge generated from the simulation emerges among the participants. What are given priority are not the specific procedures by which decisions are reached, or specific instructions about how to carry out tasks, but rather the outcomes and goals that are necessary within a dynamic environment. The procedures and decision-making strategies are developed within the simulation itself. This emergent form of learning that takes place within simulations has been noted as an effective platform within which expertise can be developed and honed.

The specific OpSim methodology used here has several features that set it apart from other simulation exercises. Simulation-based exercises are used for a many purposes, primarily economic behavior modeling; emergency event scenarios including war games, flight simulations, firefighting, and rescue operations; and change management techniques. Most behavioral economics simulations conducted in experimental laboratories in universities rely on the use of novices (often undergraduate or graduate students) in context-free environments (lab or classroom setting). Many examples, such as the classic "beer distribution game," ask the novice participant to engage in a given exchange scenario and to maximize benefits and minimize cost, with the goal of modeling economic choices or achieving learning objectives for students. Conclusions drawn from these studies may translate to real-world behavior in some cases; however, the real workplaces rarely offer pure "novices" and the "learning" that takes place in these kinds of games is difficult to transfer to new environments that are often bound with specific tasks, constraints, and trade-offs not represented in the simulated version. Similarly, change management games are often directed at getting participants to an "Aha!" moment, in which they realize that their ways of thinking were all wrong and are intended to direct them to a new framework, with a new perspective on how to achieve goals. Yet in many of these simulations, participants are not engaged with tasks relevant to their actual jobs, they are rather engaged with a way of thinking. In any case, the results from these exercises are also difficult to transfer to real-world solutions and objectives. Last, event scenarios like war games and flight simulators often do an amazing job at replicating real-world environments. However, these kinds of simulations are primarily useful for learning a specific, standardized set of procedures, plans, or strategies. These kinds of simulations often predesign a particular method to which the participants must adapt. The purpose of these simulations is not to allow design solutions to emerge among participants but rather to have participants "learn by doing." For example, in flight simulators novice pilots (or experienced pilots learning a new model) crash a number of planes until they learn the correct procedures for how to fly.

In contrast, when designing simulations that address the specific needs of complex and volatile business environments, many of these methods either do not apply or cannot achieve the outcomes necessary to produce significant change. Designing organizational change for business is not a matter of relaying a standardized set of procedures to employees but rather involves navigating the uncertainties in which the high-level goals are often clear (profit, efficiency, etc.) but the means of achieving them are often unclear and the incremental targets necessary to achieve those goals are rapidly evolving.

Attempting to harness the kind of expertise within simulated environments, during the past 15 years we have been developing an accelerated learning technique we call the OpSim. Developed initially from a study of workers using material requirements planning systems for manufacturing (Scribner, DiBello, Kindred, & Zazanis, 1992) in two different factories, OpSims involve the notions of learning as the reorganization of knowledge into new frameworks or guiding heuristics rather than learning as the "addition" of new knowledge. Although learning happens both ways—as reorganization and as an addition process—only the reorganization of knowledge led to real changes in behavior, or what we referred to previously as implicit expertise. The idea of the OpSims is that many months of incidental learning is compressed into days when OpSims are deliberately designed to replicate the learning opportunities that we observed in some workplaces.

BASIC DESIGN OF THE OpSim

We start the design of an OpSims by beginning with a business "ideal" that the participants must develop the ability to achieve. Using a computer program that we have written for this purpose, we develop a scenario of events (costs, profits, product flow) that is driven by the ideal assumptions and present that as a "normative ideal." We then develop all the materials and artifacts that support this scenario as well as competing, less functional methods and ask the participants to actually run a company with several interacting functions, attempting to meet or exceed this ideal under a time pressure (e.g., often a "month" is 20 min in a manufacturing exercise). At each time unit interval (e.g., 20 min), the participants' progress is plotted on a chart against the ideal; usually the metrics are automated and a computer screen or an LCD projector shows the results. At any moment, participants can glance at these charts and tell how far they are from the ideal on any of the parameters being measured during the exercise.

Participants always play the "game" twice. When they go through it the first time, they nearly always construct a solution to even a novel problem that fits with their experience, even when explicitly instructed to avoid doing so and even when they know ahead of time that old methods will not work. In fact, the participants are rarely aware they are replicating their normal methods. Rather than interfere with this tendency, the facilitators allow the participants to continue, sometimes even increasing the pressure on them to perform, while carefully documenting the financial and material problems associated with their decisions and plotting the group's performance against the ideal. By the end of the first day, the "workplace" is in crisis and the participants are realizing that their resources are being expended to react to mounting problems. Of importance, the group invariably "fails" in a way that mirrors their current problems in the real workplace. Furthermore, the financial profile in the OpSim at the end of Day 1 often reflects what is happening in the actual organization.

At the start of the second round of the exercise, participants are given the data on what they did, as recorded by the automated systems. The spreadsheets and graphical displays are provided that show both the ideal curves and the actual curves from the day before. The participants discuss among themselves three issues: what went wrong, what we will do differently this time, and how will we know it is working. New solutions now seem obvious. The participants are then given an hour or two to make a new plan for "winning" on the second try.

During the second try, the participants must make their "new" plan work by running the OpSim again. They are under the same time pressure as before, making it nearly impossible to reflect on things or solve problems in a methodical fashion. Also, the details of the company and the other materials will be changed so that participants cannot rely on memory to win the game. The idea is to engender new automated responses and ways of looking at the problem. The groups invariably perform well. The question is why does this happen?

From our experience, we think that OpSims accelerate learning because they elicit the implicit knowledge that the worker has to bring to the problem and at the same time select against non-workable strategies through experiences of failure. That is, participants in our interventions learn by "unlearning" their heuristics and reorganizing their extensive content knowledge more than really learning something new. We return to this idea after describing what happened in our Biotech OpSim.

THE BIO-MANUFACTURING PROJECT

At the bio-manufacturing company, the business challenge in our project was threefold:

1. Reduce the high level of back orders.
2. Empower frontline workers to devise a solution while holding them accountable for the performance of the company.
3. Sustain the results and increase the chances that the solution would transfer back to real work.

To address these challenges, we designed a fast-paced OpSim exercise that replicated the shop floor's major functional areas. We used an undeveloped section of the company's facilities, building a "shop floor" within a 40 × 60 ft space. Using our software, we modeled the ideal financial profile of a company with growing sales and no missed shipments. Using a method of calculating the net present value of the company, we also derived a "tracking stock," showing how high performance would translate into a rising stock price. At the start of the exercise, we simply told participants that in order to win, they had to meet all customer orders on time. We did not target or even specify the skills or means for greater responsiveness; rather we emphasized only the goals (on-time delivery, no missed orders, increasing volumes, and a revenue and profit goal) and challenged the groups to develop a solution. The only feedback they received was a dynamic dashboard showing the financial impact of their decisions and actions. This was projected on the wall from a laptop so the participants could see in a relatively "live" fashion how they were doing relative to the "ideal" on key factors such as the following:

1. Orders fulfilled
2. Cost of goods sold
3. Gross revenues
4. On-time status of work in process at all major stations.
5. On-time status of customer orders

Four groups of 20 to 25 people participated in the simulation exercise for 10 hr each. Each group got two chances (playing the game once a week for 2 weeks, for 5 hr each time) to achieve the target outcomes. In the 5-hr period, the team was given 1 hr to plan and organize their company and then had to complete "12 weeks" (equivalent to one fiscal quarter of business) in the remaining 4 hr. Therefore, it was conducted under a compressed time frame with each "week" lasting only about 20 min. All teams were competing with all other teams. The team with the solution that solved all problems and accomplished or exceeded the revenue, on-time delivery, and profit goals would be the "winner" and their solution would be implemented on the actual shop floor. As part of the project, senior management agreed to support the implementation of any changes that proved successful in an OpSim. In other words, the OpSim was seen as a kind of opportunity to invent, rehearse, and refine an operational approach to the goal. Success in the OpSim was seen as proof of a plan's worthiness. Director-level management participated in the OpSim to experience the business value of emerging innovations. They played in roles that would be directly affected by the innovations: customers, research & development personnel trying to get new products launched in manufacturing, and the shipping department.

FAILURE AND REORGANIZATION

All of groups failed on their first time through the game. In fact, they replicated their lateness, cost, and inventory problems almost exactly as they were manifesting in real life, with similar financial consequences. In other words, they ran a back order rate of about 40% resulting in as much as $800,000 of customer orders on hold and at risk of being cancelled during any given game period. We also designed the forecasts in the OpSim to predict customer orders to near perfection. As such, we removed the "excuse" of a bad forecast as the reason for the high back order rate, which can be a common response when workers fail to meet delivery goals. The consequences were obvious and painful. The OpSim companies suffered declining stock prices as revenue forecasts were not met.

In the second round, after given a clean slate and a chance to retry the game, the groups were able to resolve the problems and failures they confronted in the first round. In fact, all groups exceeded the desired outcomes. In addition, they accelerated the launch of many new products by several game "months," increasing revenues beyond those projected and causing the stock to spike as they beat out virtual competitors trying to launch similar offerings. The groups achieved these goals in innovative ways and developed solutions that they had not previously considered. In the second round, rather than working faster or following new procedures, they developed a greater understanding of manufacturing's role in the total business. Rather than focus on local goals, they focused on tailoring their activities to higher level goals, such as revenues, profits, and the impact of these on stock price. Thinking this way led them to redesign the shop floor flow of material and information, minimizing product movement and centralizing some activities. Although there was a "winner," all the teams found a similar solution to the back order problem and achieved similar results. In time, the winning team's solution was implemented in real life.

Looking at Figure 1, we can see clearly the learning taking place within the simulation. Notice that during the first run-through, (represented by the lines with circles) even the best performing team performed worse than the worst performing team in the second run-through. Furthermore, all of the teams improved in the same way, each increasing their ability to cut losses with solutions to reducing the back order problem.

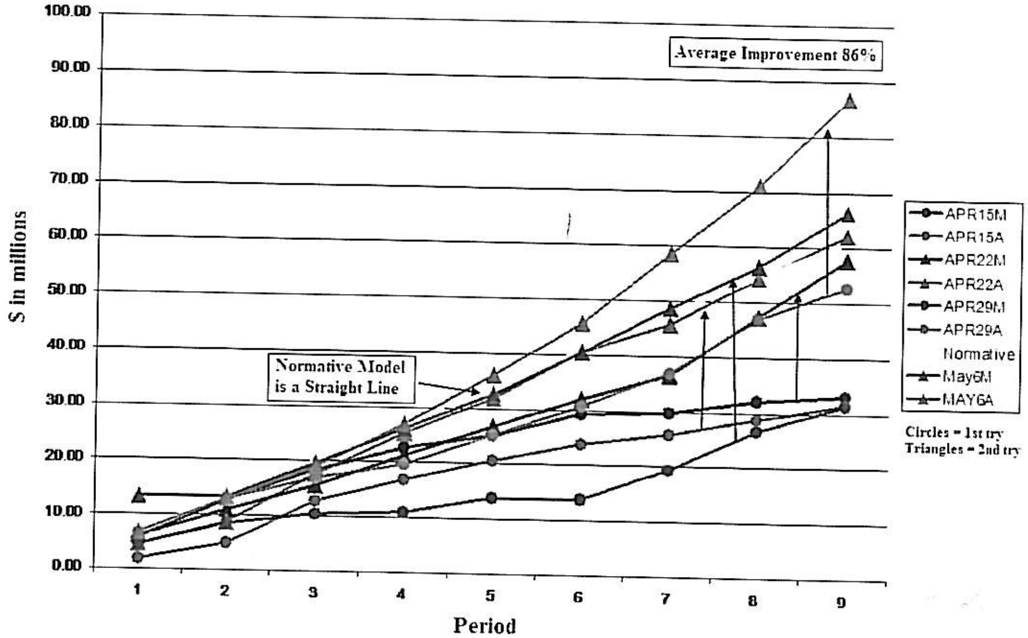

FIGURE 1 Improvement in throughput during the simulation between Day 1 (circles) and Day 2 (triangles).

SOLUTIONS GENERATED BY THE GROUPS

When we returned to the company a year later, many of the solutions they developed in the simulation had been put into practice. They implemented the shop floor design and metrics that emerged from the winning team during the exercise. As in the exercise, the real-life metrics focused on the high-level financial impact of day-to-day decisions and actions. They had implemented a system to track back orders based on those products that had generated the most revenue, and the back orders (in dollars) were posted daily. In fact, the workers chose to use an LCD projector exactly like the one used in the OpSim to get "live" feedback. Each supervisor was rated on compliance to the forecast, also on a daily basis. In addition, they reorganized the structure of teams (both in the simulation and subsequently on the actual shop floor). For example, prior to the simulation each team responsible for different parts of the bio-manufacturing process was also responsible for their own vialing and packaging. Prior to the OpSim, there was no centralized vialing and packaging. During the OpSim, all teams realized the need for centralized vialing and packaging, and the best solution to this problem was generated within the OpSim and subsequently implemented on the shop floor, which contributed significantly to a drop-off in back orders. As can be seen in Figure 2, within months the back order problem was reduced and stabilized by the same workers who thought it was an unsolvable problem. Instead of "unpredictable" volatile shifts in back orders that generated a lot of lost revenue, within 4 months they had their back order problem under control. Further, they seemed to have much greater knowledge of and interest

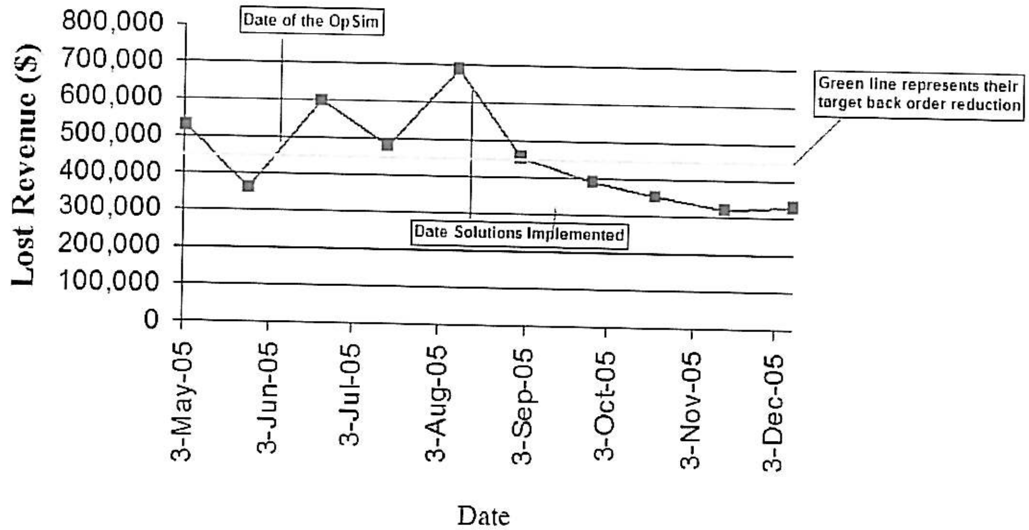

FIGURE 2 Actual revenue lost because of back orders before and after the simulation.

in what the company's competitors were doing and how their company compared in the broader marketplace.

Two years later the shop floor had maintained its performance objectives and associated financial benefits. As they achieved greater levels of back order reduction, they continued moving the "target" lower. Lost revenues from back orders average only $25,000. The nature of the actual bench work done by these workers has not changed much, but the company as a whole has had to become more customer and market responsive and shorten production lead times to remain competitive. In addition, the shop floor workers remained attentive to higher level goals rather than focusing on the local deadlines and tasks of their specific role in the organization.

DISCUSSION AND CONCLUSION

We have told a story of workers at a biological manufacturing plant and their success. The challenge now is to explain what caused their success (see Figure 3 for pictures). Was it the OpSim experience and its emphasis on manufacturing's contribution to the total company? Was it the fact that the workers could implement the things they discovered in the OpSim? Did they enjoy continued success because of the sustaining metrics that were exported from the OpSim to the shop floor? Several challenges present themselves when doing research in naturalistic settings, with real companies where classical experimental methods are not possible. However, the results are suggestive. The fact that this type of simulation had a quick and dramatic impact suggests some things about learning and the nature of in situ cognition, particularly considering that changes did not occur until the teams attempted a second time, and considering all four teams failed the same way the first time, and the succeeded the same way the second time.

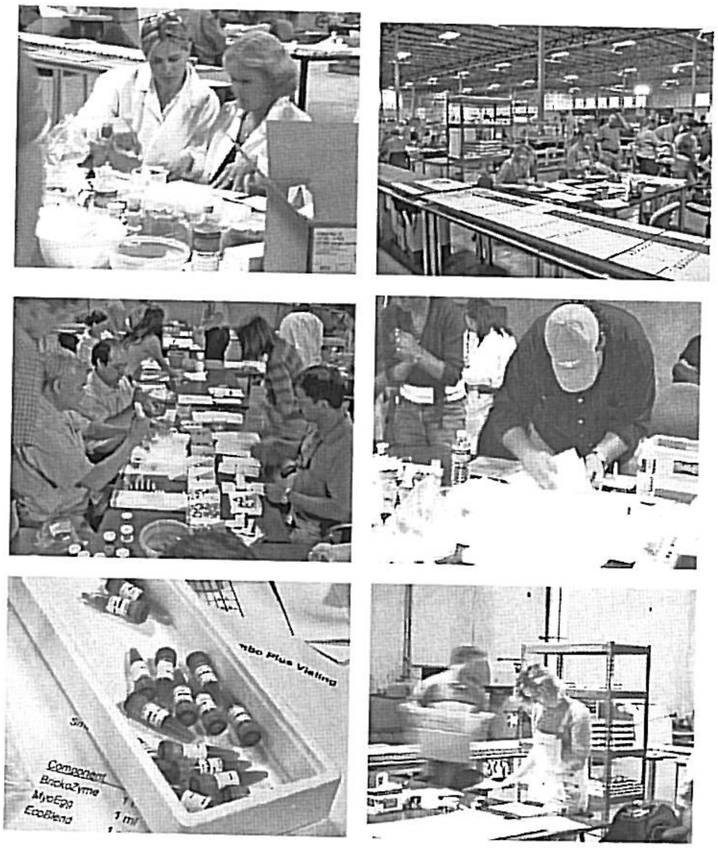

FIGURE 3 Pictures from the OpSim: Teams moved from isolated teams toward centralized operations.

Learning as Cognitive Reorganization

The simplest explanation of what happened resides with Piaget's (1977) functional invariants. Although Piaget's framework is not typically used to explain cognitive shifts in the thinking of adults, we can see clearly how—in a domain specific sense—what occurred with the workers was essentially developmental and epistemological in nature. Rather than learn something new in an additive fashion, the workers first attempted to "fit" their current assumptions and work practices into a situation, even though they were explicitly aware of the new goals in the simulation (e.g., no back orders) and believed themselves that they would have do something different to "win" the game. Not surprisingly, they not only failed but also replicated their real-life performance problems (i.e., 40% back orders). In other words, they "assimilated" their "default" schemas to the task at hand. Their methods did not work, and given the explicit form of the feedback (a performance chart that was updated every 15 or 20 min and projected on a screen) the inadequacies of the group's approach were obvious and documented in detail. At this point, we believe they experienced disequilibrium and their understanding of the situation underwent a process of iterative accommodation. This is observable in the team's data. About halfway through the exercise, the approach to the tasks took on changes and refinements. However, the tasks are still by and large difficult and frustrating for the group. An interesting feature of OpSims is that all teams find them much less challenging on the retry a day or more later. This occurred with these workers as well. We believe here that by the time they went through the simulation the second time a week later, they had found they had reorganized their content knowledge according to a new framework that was more adaptive to the goals at hand. In other words, just as the prior approach was assimilated almost reflexively the first time, the new approach was assimilated without effort the second time with marked success.

However, a Piagetian approach only takes us as far as understanding what might have happened within the individuals. It does not explain where the goal comes from and how changing goals and feedback can influence new models of thinking and acting. For Piaget, the prior approach would be as developmentally advanced as the one that replaced it. This was adaptive, for the most part, until the workplace structure and goals had changed. To address the role of changing context of development, if we look at the process in terms of Vygotsky's activity theory, cognition is always developing in service of a leading goal or activity. In this analysis the zero back order goal was a leading activity in the Vygotskian sense. The socially constructed requirement acts as a context that constrains what develops in that it determines what is adaptive to the situation. In other words, Piaget's functional invariants combined with activity theory's notion of leading activities in a social space, best describe the underlying mechanisms we believe are at work in the OpSim.

The principle of "equilibration," which describes the way in which humans harmoniously integrate prior knowledge into strategies for solving problems in novel situations, is central to Piaget's approach. This Piagetian model involves what he terms the "functional invariants"—assimilation (applying existing schemas to familiar aspects of a novel situation); accommodation (incorporating novel information to modify existing schemas), which lead to an equilibration of schemas through the processes of disequilibration; and reorganization. Disequilibration describes the confrontation between existing schemas and incompatible feedback from the environment and from the existing community of practice within which the activity takes place. It is through the process of disequilibration that the strategies of assimilation and accommodation (the basis of learning and development) are activated. As such, disequilibrating existing mental models becomes a central feature of the accelerated learning dynamic within an OpSim.

However, Piaget's developmental model applied to the organism as a whole and did not fully encompass the complexity of developmental processes in response to different leading activities. Drawing from activity theory, we place leading goals as the central anchor of the learning process. Activity theory, rooted in the work of Vygotsky (1987), posits that behavioral and mental processes are develop through interaction with others organized around sequences of motivated action toward a mutually constituted goal. This is especially true for workplace and formal organizational dynamics. Activities are always part of a system of social life using a specific set of tools, symbols, and modes of action that reflect the particular historical development of a culture of practice. As such, the concrete content, meaning, and motivations within an activity space are constantly changing, creating various domains of expertise tied to specific activities within specific environments.

Workers (in this case) who must develop expertise in response to dynamic conditions with changing goals and leading activities cannot simply rely on a single schema for organizing expertise. They must also be able to transfer that expertise across multiple domains and adapt flexibly to rapidly changing goals and leading activities. Therefore, the learning outcome to ensure that workers are not simply proficient in carrying out tasks to meet demands, but that they are able to redeploy existing content expertise into new and adaptive frameworks. If the goal of OpSims is to engender new modes of thinking and behaving in response to dynamic environments, old modes must first be "unlearned," which is achieved through a process by which old, default mental models are activated, brought into play, and fail to produce the expected results. At this point, we believe classical Piagetian mechanisms apply; the assimilated model is reorganized to accommodate the situation, and the net effect is a kind of unlearning of the default mode that leads to reorganization in participants' mental models in line with key organizational outcomes.

Existing, maladaptive mental models are weakened through several core features of the OpSim design. Symbolic density combined with time compression, inducing stress, are the triggers that activate the response of the default modes. The greater the density, the greater the extent to which the default mental models are assimilated and automatically take over organizing decisions, perceptions, and actions. Real-time, granular metrics that track and give feedback on performance against nonnegotiable outcomes allow participants to examine the sources of success or failure against existing schemas. As such, part of our simulation exercise involves an engineered "failure" of the default mental models. The OpSim, then, acts as a highly time-compressed, miniature version of the same sorts of activities present in their actual jobs—including nonnegotiable goals—which allow workers to rehearse strategic goals, confront failure, and reorganize non-adaptive frameworks in line with leading activities with less risk to actual operations.

Given the constraints of the research, we cannot say for certain that the process disequilibration and reorganization happened to the same degree for all participants, or that, for some of them, it even occurred at all. However, in the end, in terms of organizational outcomes, this may not matter. For our purposes, because the organization as a whole is responsible for outcomes, as long as a critical number of participants engages with this process of learning through unlearning, and does so in the right way, we can claim that the team as a cognitive system has been through the "accelerated learning" process: confront failure, disequilibrate maladaptive default mental models, and shift its expertise into a new framework in line with organization level goals.

Resolving the "Means–Ends" Inversion of Empowerment

The increasingly dynamic nature of the business world only increases the pressure on organizational development efforts to contribute to the company's success. For example, we have studied $500 million companies that disappeared in less than 2 years after failing to perform competitively. In those firms we saw empowerment efforts that fell into a "means–ends inversion," where psychological empowerment becomes the goal at a cost to the performance of the organization. In light of debates about the effectiveness of empowerment initiatives, we believe a key ingredient that has been largely ignored in the discussions is accountability. In the context of the OpSim, empowerment has emerged as getting to use one's knowledge of the work (content) to build a skill set and approach (framework) that contributes to the organization's performance in real terms. Our view is that management development, process improvement, operational excellence, or worker empowerment has no meaning outside the central purpose of an organization. Thus, in a sense, using OpSims overcomes some of the normal problems with empowerment efforts conflicting with the goals of the organization. Furthermore, it places empowerment not as an end in itself but as a means to discover and achieve the central purpose of the organization at all levels.

Although we do not have time in this article to review the long tradition of empowerment theories and initiatives, we touch on two problems that impede successful attempts at worker empowerment. In the first case, organizations must be careful about implementing initiatives that use "empowerment" in name, without actually handing over critical decision-making authority and removing the hierarchical barriers that harness frontline expertise. On the other hand, initiatives focused too heavily on the emancipatory aspects of empowerment and removing organizational power hierarchies, although noble goals in themselves, potentially face a "means–ends inversion," whereby higher level organizational goals are not being served. We believe that both of these approaches risk failing the long-term needs of both workers and organizations. Yet we feel the problems inherent in these approaches can be resolved in part through the issue of accountability, wherein frontline workers are forced to confront complex problems and develop solutions against nonnegotiable outcomes that satisfy both low- and high-level demands.

Because our OpSim exercises are always designed so that the new goals must be met to succeed in getting through them, the new frameworks that people develop are always fully adapted to organizational goals. In some ways, we accelerate and intensify the original process through which a workplace culture of practice shapes cognition normally. Some have compared our exercises to flight simulators, where the pilot must constantly adjust his or her reactions to events so as to fly the plane on course without crashing it. When trying a simulator for a new model of plane, even experienced pilots will crash the first few times, as they adjust to the new features of the new plane and any new risks associated with its design. Similarly, our participants always get the opportunity to go through our exercises twice. The first time they always "crash" their companies, but they always excel on the second try. The difference between OpSims and a flight simulator, however, is that workers are held accountable to nonnegotiable outcomes, but the solutions they generate to meet those goals emerge from within the teams. As such, they are not simply being "trained" in a particular process that leads to a goal, they are being held to specific outcomes while also designing the process of achieving those outcomes.

More to the point, experienced low-level workers who participated in these interventions developed approaches that go beyond what would be possible with simply starting over with new workers or attempting to "train" them with best practices used elsewhere. This kind of approach is possible because of their considerable content knowledge; they emerge from our simulation exercises with new frameworks but retain their rich experiential content. The new framework redeploys their rich content knowledge in innovative ways.

This approach recasts the notion of worker empowerment somewhat. Instead of focusing solely on increased decision making authority for low-level workers, the OpSim empowers low-level workers by holding them accountable to contributing to high-level organizational goals and resolving contradictory objectives as if they were high-level managers. In their OpSim exercises they developed these solutions in miniature. Back at work, they found ways to institute and sustain these solutions. In this case, empowerment is organized by central goals that of contribute directly to overcoming challenges that impede the organization's success. Decision making in naturalistic and volatile environments will never be accurately modeled by a unified set of procedures and processes (Lipshitz, 1995), and thus top-down hierarchical authority is often not the most effective way to structure decision making in such environments. Part of the success of OpSims, we believe, is based on the fact that, rather than imposing a set of instructions for new learning models, they mobilize workers' expertise and allow workers' to modify and adapt that expertise to changing conditions. The OpSim mimics the workers' expertise in revising mental models and adapting cognitive frameworks to address dynamic conditions.

Thus, the "training" involved in NDM settings may not be elaborate skill acquisition protocol but rather may be a minimally controlled setting within which novel and adaptive skills and decision-making protocol are given room to emerge. Once these workers adopt an adaptive framework, with solutions they have generated themselves, supported by an appropriately empowered organizational structure, the organization has the ingredients necessary to sustain long-term expert performance, because core expertise can be continuously elicited and modified.

As such, the OpSim does not address the issue of power hierarchies directly. The goal of the OpSim is not to redesign power hierarchies within organizations, as it is not our position to determine how the organizational hierarchy should be arranged. Furthermore, we do not believe worker empowerment initiatives can be successful in the long term without contributing directly to high-level organizational goals. In other words, decision-making authority must be arranged in such a way that matches accountabilities among organizational members. If the work of a so-called low-level employee significantly impacts bottom-line performance, then decision-making authority must be allocated in such a way that the employee is aware of, accountable to, and responsible for decisions related to these high-level goals. Thus, the OpSim is designed to harness all of the available expertise within the organization to meet high-level demands, where empowerment acts as a means to an end, not an end in itself. In doing so, rigid power hierarchies that are not in the service of high-level organizational goals quickly become irrelevant. Because of the immediate feedback, time pressure, and granular performance metrics, organizations can track which arrangements of power and decision making best service the goals of the organization. After simulating the impact of these arrangements, they can then make structural decisions based on a symbiosis between workers' expertise, decision-making authority, and organizational performance.

With changing business environments in which frontline workers are called upon to make mission critical decisions, the issue of empowerment becomes central. In this particular study, we believe that the effectiveness of training in typical volatile business contexts may be tied to empowering front line workers to make "mission critical" decisions while holding them to mission critical outcomes. Workers given new accountabilities must also be empowered to see the connection between their work and mission-critical outcomes, and possibly greater authority to mobilize their often-underutilized expertise to meet the urgent needs of the organization.

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