Chapter 4
Organizational Memory

4.1 Introduction

What do organizations learn as they gain experience in production? Where is this knowledge embedded within organizations? What are the consequences of where knowledge is embedded for organizational performance? This chapter begins with a discussion of what is learned as groups and organizations gain experience. A more general discussion of organizational memory and various "retention bins" or "repositories" of organizational knowledge follows. Examples of knowledge embedded in various repositories drawn from our studies of manufacturing and service industries are provided. Empirical evidence on the extent to which organizational knowledge is embedded in these various repositories is described. The chapter concludes with a discussion of the implications of where knowledge is embedded for important aspects of organizational functioning and effectiveness.

4.2 Sources of Productivity Gains

Many researchers have speculated about factors responsible for the productivity gains observed in organizations with increasing experience. For example, Joskow and Rozanski (1979) discussed the following factors as contributors to the productivity gains observed with increasing experience: routinization of tasks, more efficient production control, improved equipment design, and improved routing and material handling. Thus, these researchers emphasize changes in the task and technology as contributors to productivity gains associated with experience. Hayes and Wheelwright (1984) listed a broader set of factors as facilitators of organizational learning. According to Hayes and Wheelwright (1984), organizational learning curves are due to individual learning, better selection and training, improved methods, enhanced equipment and technology, more appropriate division of labor and specialization, improved product design, substitution of capital for labor, incentives, and leadership. Similarly, Porter (1979) noted that with more experience, firms learn

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to make methods more productive, to design layout and workflow more efficiently, to coax more production out of machinery, to develop specialized new processes and product design modifications that improve manufacturability, and to institute better management control. Skilton and Dooley (2002) distinguished between operating knowledge, held by direct production workers, and structuring knowledge, held by managers. Structuring knowledge describes how to structure or organize operations most effectively while operating knowledge describes how to perform most effectively within an established structure.

In our interviews with managers at manufacturing plants about their views of the most important determinants of organizational learning curves, our respondents emphasized the following (1) increased proficiency of individual workers; (2) improvements in the organization's technology, tooling, and layout; (3) improvements in its structure, organization, and methods of coordination; (4) and better understanding of who in the organization is good at what (Argote, 1993). This last factor is similar to the concept of transactive memory, which Wegner (1986) developed to describe the knowledge of who knows what that develops between individuals in close relationships. Better understanding of each individual's skills enables the organization to assign tasks more appropriately so as to take better advantage of each individual's unique capabilities. Knowledge of each member's special expertise is also beneficial because members of the organization know whom to go to for help or advice about specific issues.

These myriad factors believed to affect learning can be classified into three general categories: improvements in the performance of individual employees, including direct production workers, managers, and technical support staff; improvements in the organization's structure and routines; and improvements in the organization's technology. Examples of improvements in each of these categories will now be discussed. These examples are drawn from our field studies of learning in manufacturing and service organizations.

4.2.1 *Increased Individual Proficiency*

Most discussions of factors responsible for organizational learning curves cite learning by individual workers as a key factor (e.g., see Hayes & Wheelwright, 1984; Yelle, 1979). A long stream of research in psychology has documented that individual performance improves as individuals acquire more experience with a task (Graham & Gagne, 1940; Thorndike, 1898; Thurstone, 1919). Reviews of the large body of research on individual learning can be found in Anzai and Simon (1979), Newell and Rosenbloom (1981), and Mazur and Hastie (1978).

Our interest is in individuals working in organized settings. What qualifies as examples of improvements in individual performance that occur in ongoing groups and organizations as individuals gain experience in production? Many examples of individuals becoming more skilled at their particular tasks can be found in our study of fast-food franchises. For example, pizza makers typically became more proficient at hand-tossing pizza dough and transforming it into a pizza shell as they acquired experience. Much of the knowledge about how to hand-toss pizza was tacit and therefore difficult to articulate to others (Nonaka, 1991; Polanyi, 1966). This knowledge remained primarily embedded in the individual workers who had acquired experience with the pizza-tossing task.

We also observed improvements in the performance of individual workers in manufacturing plants. At one plant we studied, a second shift was introduced almost 2 years after the plant had been in operation with one shift. Workers on the new shift worked side by side workers on the first shift to learn their jobs. Workers on the new shift were gradually "weaned" from their experienced counterparts until the new employees were working independently on the second shift. Through observing workers on the first shift and gaining experience with the task, workers on the new shift learned their individual jobs and became very proficient at them.

4.2.2 *Modifications in Technology*

Modifications in technology are another major contributor to the productivity gains observed in organizations with increasing experience. By technology, we mean equipment, including hardware and software (cf. Amber & Amber, 1962; Barley, 1986; Blau, Falbe, McKinley, & Tracy, 1976) used in production. An example of modification in technology that derived from experience in production can be found in the paint shop at one of the truck assembly plants we studied. The plant experienced problems in its new highly automated paint shop. When light-colored products followed dark-colored ones, vestiges of the dark color remained on the subsequent, light-colored product. This was clearly unacceptable. Plant managers and engineers tried various approaches to remedy the problem. The most effective solution that was developed involved dedicating particular paint booths to particular dark colors. Thus, only products of the same dark color would be processed through each booth. If any residue paint remained in the system, it would not be harmful because all the products going through the booth were the same color. While dedicating a paint booth to a particular color resulted in some loss in flexibility for the system, the lost flexibility was more than offset by the improved product quality and the reduced waste. This manufacturing example illustrates how knowledge acquired via learning by doing can lead to modifications in an organization's technology. Knowledge was embedded in the "software" and the "hardware" of the paint shop that enabled the organization to produce a higher quality, less costly product.

We also observed several examples of improvements in technology in our study of fast-food franchises (Argote & Darr, 2000). Technology in the context of these pizza stores includes the equipment, such as ovens, and tools used to make pizzas, as well as the physical layout of the stores. The "cheese spreader" is an example of an innovation developed through production experience that became embedded in the organization's technology. Achieving an even distribution of cheese across a pizza is a desired goal. Too much cheese decreases profit margins, whereas too little cheese decreases customer satisfaction. A manager at one of the stores we studied decided that spreading cheese by hand was not the best method. The manager believed that the problem was analogous to spreading fertilizer on a lawn and that some type of "spreader" was needed. The manager experimented with various configurations of plastic dishes and metal screens to develop a tool that would help pizza makers use a consistent amount of cheese and achieve an even distribution of the topping. The final version of the "cheese spreader" tool was a plastic cone with holes that sat on feet several inches above the pizza. A pizza maker would pour grated cheese into the cone and the cheese would fall in a consistent pattern over the pizza. This example illustrates—in a very different organizational context—how knowledge acquired via experience can be embedded in an organization's technology.

4.2.3 Elaborations in Structure and Routines

Elaborations in structure and routines made as organizations gain experience in production also contribute to organizational learning. One such elaboration we saw at a manufacturing plant involved changing the structure of the industrial engineering group. A decision was made to deploy the industrial engineering group that had previously been centralized in one area of the plant to various areas on the plant floor so that the engineers could be more responsive to production problems. Thus, the industrial engineers were shifted from a functional-type organization where they were centralized in one area to a product-type organization where they were decentralized to various areas on the plant floor. The decentralized organization enabled the engineers to respond more quickly to issues on the plant floor. In this example, knowledge about how to be more responsive was embedded in the manufacturing plant's structure.

Another example of knowledge embedded in routines occurred in a manufacturing plant we studied. The particular routine involved preparing the products (trucks) for painting: painting two-tone trucks was challenging because workers had to mask the areas of the truck that were not to be painted a particular color by taping large sheets of protective paper over the appropriate areas. As experience was gained with the task, a better method for placing the protective paper was discovered. Initially, workers masked the area of the truck that was not to be painted a particular color to protect those areas and then painted the rest of the truck the desired color (e.g., white). They then reversed the masking by placing protective paper over the area that had already been painted the desired color (e.g., white) and painted the remainder of the truck the second color (e.g., red). This process required two stages of carefully masking the truck with protective paper. A new method of masking was discovered that required only one round of masking. All of the truck was painted one background color (e.g., white). The parts of the truck that were to remain the background color were then masked and the truck was painted the second color (e.g., red). The new process saved considerable time because the trucks had to be masked with protective paper only once. The new method, which required fewer labor hours and less material to achieve the desired two-tone paint job, ultimately became embedded in a routine that all workers used.

We also observed knowledge embedded in an organization's routines in our study of fast-food franchises (Argote & Darr, 2000). When deep-dish pizza was introduced at the pizza stores, all stores experienced a persistent problem with the new product. The usual method of distributing pepperoni on pizzas was to distribute it evenly over the pizza before the pizza was cooked. Although this method worked for regular pizzas, it did not work well for deep-dish ones. When pepperoni was distributed evenly on deep-dish pizzas, the pieces of pepperoni would all move into the center in one "clump" as the pizza cooked and the cheese flowed. Various methods of dealing with the problem were implemented. The most successful one involved distributing the pepperoni on the pizza before it was cooked in a pattern that resembled spokes on a wheel. As the pizza was cooked, the flow of the cheese distributed the pepperoni pieces (more or less) evenly over the pizza. Thus, knowledge about how to distribute pepperoni evenly became embedded in a routine. This routine proved to be very effective at achieving an even distribution of pepperoni. The routine is now used by virtually every store in the corporation.

4.3 Repositories of Organizational Knowledge

How do these examples of sources of productivity gains relate to more theoretical discussions of organizational memory or of where knowledge is embedded in organizations? Stein (1995) defined organizational memory as the means by which knowledge from the past is brought to bear on present organizational activities. According to Stein (1995), "memory is a persistent record not dependent on a tight coupling between sender and receiver" (p. 22). Similarly, Walsh and Ungson (1991) defined organizational memory as stored information from an organization's past (see also Anand, Manz, & Glick, 1998) and Casey (1997) defined it as shared interpretations of the past.

Where is this knowledge from the past embedded within an organization? Levitt and March (1988) indicated that knowledge is embedded in an organization's routines and standard operating procedures (SOPs), its rules (March, Schulz, & Xuequang, 2000), in its products and processes, in its technologies and equipment, in its layout and structures, and in its culture and norms about how things are generally done. Similarly, Walsh and Ungson (1991) conceptualized five "retention bins" for organizational memory: individual employees, the organization's culture, its SOPs and practices, roles and organizational structures, and the physical structure of the workplace. According to Starbuck (1992), in knowledge-intensive firms, knowledge is embedded in individuals, in physical capital (including hardware and software), in the organization's routines, and in its culture.

Yates (1990) provided a fascinating account of the evolution of organizational memory from knowledge that resided primarily in individuals to knowledge that resided in supra-individual form. In the early 1800s, organizational memory was primarily embedded in individuals. According to Yates (1990), the growth of the railroads changed that. The changes were brought about by the need to coordinate a geographically dispersed business where lapses of coordination could result in serious accidents. For these firms, timetables and detailed operational procedures became part of their way of doing business—part of their organizational memory.

An elaboration of organizational memory occurred on a more widespread basis with the advent of scientific management at the turn of the century (Taylor, 1911). One of the principles of this movement was to capture the knowledge of individuals so that organizations would not be dependent on them or vulnerable to their turnover. Written records were elaborated; manuals were developed that described an organization's rules and procedures. Reporting systems were also established to transmit information up the hierarchy. Thus, the late 1800s and early 1900s witnessed a shift from organizational memory being embodied primarily in individuals to its embodiment in records, rules, and procedures that did not depend on individuals.

Nelson and Winter (1982) focused on routines as repositories of organizational knowledge (see March & Simon, 1958 and Cyert & March, 1963, for earlier discussions of organizational routines). Rerup and Feldman (2011) articulated how routines developed from learning from experience. Gersick and Hackman (1990) described routines at the group level of analysis. Carley (1996) provided evidence from a simulation study that the use of routines or SOPs can enhance the accuracy of organizational decision making. Routines have been theorized to be a source of change (Feldman & Pentland, 2003) as well as a source of stability.

According to Nelson and Winter (1982), routines are programs or repetitive patterns of activity. In order for organizations to function effectively in routine conditions, individuals must be familiar with the procedures their jobs require and know when particular routines are appropriate. Although each individual must know his or her particular job, the individual does not need to know the jobs of others or the routines that guide the organization as a whole. Indeed, the scale and complexity of many organizations make it difficult to achieve coordination through centralized information or control systems that describe all the routines used by the organization and the interrelationships among them.

Theraulaz and Bonabeau (1995) described a fascinating example of the implementation of routines in a wasp colony. The researchers noted that while individual insects possess a limited repertoire of routines, insects are collectively capable of performing complex tasks, such as nest building. Theraulaz and Bonabeau cited an early study by Grasse showing that coordination of nest-building activity in termites does not depend upon interactions among the workers themselves but rather depends upon the structure of the nest. The inputs of one worker are cued by the outputs of another. Actions taken by one worker modify the nest configuration, which in turn automatically triggers new actions by other workers.

This example is similar to Nelson and Winter's discussion of routines in organizations in that individual members of the collectivity must know their own routines and the triggering conditions for them but do not need to know others' routines. The nest-building example is analogous to how work is structured on many assembly lines.

Employees know their own routines. They identify which routine to implement by observing the product—either its physical condition or information cues attached to it describing its requirements. For example, an employee might observe that the next truck he or she is to work on requires an air-conditioning system—either by observing that there already are parts of the air-conditioning system installed or by reading a list of product specifications attached to the truck. This knowledge then cues particular activities by the employee that involve installing an air conditioner. This example illustrates how an individual's activities can be cued by the product and its specification sheet. Direct interaction among individual employees might not be required.

Although these discussions of organizational memory differ concerning the exact number of repositories of knowledge, the discussions have much in common. Researchers generally agree that organizational knowledge resides in individuals, including managers, technical support staff, and direct production workers; the organization's technology, including its layout, hardware, and software; the organization's structure, routines, and methods of coordination; and the organization's culture.

The framework used here to organize empirical evidence on organizational memory was presented in Argote and Ingram (2000). This conceptualization of knowledge repositories draws on theoretical frameworks developed by McGrath and colleagues (Arrow, McGrath, & Berdahl, 2000; McGrath & Argote, 2001) and used by Argote and Miron-Spektor (2011) to develop a conceptualization of the organizational context (see Chap. 2). According to the framework, knowledge is embedded in the basic elements of organizations (members, tasks, and tools) and the networks formed by crossing the basic elements. The member–member network is the organization's social network. The task–task network, which includes the organization's routines, specifies which tasks are performed and their interrelationships. Similarly, the tool–tool network describes the interrelationships among tools. The task–tool network specifies which tools perform which tasks. The member–task network is the division of labor; it assigns members to tasks. The member–tool network specifies the correspondence between members and tools. Finally, the member–task–tool network specifies which members perform which tasks with which tools.

4.3.1 *Knowledge Embedded in Individual Members*

We turn now to reviewing empirical evidence on the extent to which knowledge acquired through learning by doing is embedded in individual employees. As noted previously, most discussions about factors responsible for organizational learning curves include learning by individual employees as a key factor. Similarly, most discussions of organizational memory cite individuals as a key repository of organizational knowledge. If knowledge is embedded in individuals, then their turnover should affect organizational memory.

Engeström, Brown, Engeström, and Koistinen (1990) described an example of knowledge being embedded in an individual. The researchers analyzed a urology clinic where virtually all of the knowledge was embedded in one administrator. Few documents existed, and other individuals who were knowledgeable about the clinic had either retired or moved to a different organization. The administrator hoarded knowledge by protecting his network of personal contacts and by solving problems without explaining the rationale to his subordinates. Engeström et al. (1990) suggested that when the administrator retired, he would take all the knowledge with him. In this example, knowledge was embedded primarily in one individual. The researchers argued that his departure would hurt the clinic's performance.

Studies of the effect of turnover provide a gauge of the extent to which knowledge is embedded in individuals. What does the evidence say about the relationship between turnover and organizational learning and forgetting? David and Brachet (2011) found that turnover contributed to the organizational forgetting they observed in their study of ambulance companies. Further, the contribution of turnover to organizational forgetting was about twice as strong as the contribution of individual member skill decay.

The Argote, Epple, Rao, and Murphy (1997) study described in the previous chapter on organizational forgetting investigated whether the effect of turnover depended on the performance of departing members. We collected data that contained information on the reason employees left a manufacturing plant (e.g., whether employees were discharged for poor performance, promoted for good performance, retired, deceased, quit, "bumped" due to contractual agreements, and so on). Our results indicated that the variable representing the number of employees who were promoted out of the plant to participate in competitive apprenticeship programs on the basis of their good performance was generally negatively related to the truck plant's productivity. This study suggests that the effect of turnover on productivity depends on the performance level of departing employees: the departure of high-performing employees appeared to hurt the truck plant's productivity.

Rao and Argote (2006) examined whether the effect of turnover depended on how organizations were structured. Past work had suggested that how an organization was structured might moderate the effects of turnover. For example, Grusky (1961) found that managerial succession was less disruptive in large than in small firms. Grusky suggested that the greater use of written rules and hierarchies in the larger companies buffered them from the potential negative effects of managerial turnover.

To investigate whether structure affected the consequences of turnover, we simulated varying degrees of structure in the laboratory and contrasted the effect of turnover in highly structured groups to the effect in less structured groups. The central hypothesis was an interaction between turnover and work group structure—that turnover would affect the performance of groups that were high in structure less than that of groups low in structure, and that the performance of high- and low-structure groups would not differ when turnover did not occur. Thus, high structure was hypothesized to mitigate the effect of turnover.

The hypothesis was tested through a laboratory study in which three-person groups performed five trials of a production-type task (building origami products). The level of turnover and the structuring of activities were varied. In the no-turnover condition, the same three members worked together for the five experimental periods. In the turnover condition, one member was replaced by a new member, who had received the same training as the initial three members, at the end of each trial. In the low-structure condition, group members were not given any special instructions about how to organize themselves, whereas in the high-structure condition, group members were required to perform specialized roles and follow certain routines.

Results indicated that there was a significant interaction between turnover and structure: groups in the low-structure turnover condition performed significantly more poorly than groups in the other three conditions. Videotapes of the groups performing the tasks were analyzed to shed light on the processes underlying group performance. These analyses suggested that a major factor contributing to the poor performance of groups in the low-structure turnover condition was their continual need to reorganize around the skills of new members. For example, the group might organize around the idiosyncratic skills of one member who was good at a particular set of tasks (e.g., building crowns). When that person departed, not only was the group deprived of his or her individual skills, the group also found that its division of labor was obsolete since it was unlikely the new member possessed the exceptional skills of the old. This required a revision in the organization of work and assignment of tasks. Groups in the low-structure turnover condition showed more evidence of continual reorganizing than groups in any of the other conditions. The continual need to reorganize hurt their performance.

Other factors contributing to the poor performance of groups in the low-structure turnover condition included the difficulty the groups had accessing knowledge and the loss of critical knowledge when members left the group. The former occurred typically when one group member asked a question and another group member had to stop what he or she was doing to aid the person asking the question. This variable was negatively correlated with performance, and its incidence was higher in the low-structure turnover condition. Knowledge was coded as "lost" when a group member asked a question that no other group member could answer. This occurred only in the low-structure turnover condition. The results of this study suggest that embedding knowledge in roles and routines is effective in mitigating the negative effects of turnover. Groups in the high-structure condition were not as adversely affected by turnover as groups in the low-structure condition.

The results of this laboratory study are generally consistent with simulation results Carley (1992) obtained in her analysis of personnel turnover and organizational learning. Carley (1992) compared the effect of turnover on hierarchies and teams. A hierarchy was modeled as a three-tier organization composed of a chief executive officer, a set of assistant executive officers, and a set of analysts. Analysts made recommendations to their assistant executive officer, who in turn forwarded his or her recommendation to the chief executive officer making the final organizational decision. A team was modeled as a single-tier organization comprising analysts. Each analyst made a decision independent of the decision of the other analysts. The final organizational decision was the decision of a majority of the analysts. Carley (1992) found that while teams learned better and faster than hierarchies, hierarchies were less affected by turnover than teams. Similarly, Ton and Huckman

(2008) found that organizations that followed procedures closely were less affected by turnover than those that did not.

An individual's position in a social network moderates the relationship between turnover and organizational learning and forgetting. Whether an employee bridges a structural hole or otherwise unconnected part of a social network (Burt, 1992) conditions the effect of turnover. Shaw, Duffy, Johnson, and Lockhardt (2005) found that the departure of employees with many redundant communication links was less harmful than the departure of those who occupied structural holes.

Argote, Insko, Yovetich, and Romero (1995) analyzed whether the effect of turnover on group learning depended on the complexity of the task. We simulated varying levels of task complexity in the laboratory and contrasted the effect of turnover on groups performing complex versus simple tasks over several time periods. One theoretical argument would predict that turnover would have a more negative effect on complex than on simple tasks. Complex tasks require more distinct acts or skills (Wood, 1986). Thus, groups performing complex tasks that experience turnover would be even more disadvantaged than those performing simple tasks because the gap between the skills necessary to perform the task and those possessed by new members is greater for complex than for simple tasks. This line of reasoning leads one to predict that turnover would have a more negative effect for complex than for simple tasks.

Another theoretical argument, however, would predict that turnover would have a less negative effect on the performance of complex than of simple tasks. Several studies have found a positive effect of turnover on group or organizational performance (Choi & Thompson, 2005; Guest, 1962; Virany, Tushman, & Romanelli, 1992; Wells & Pelz, 1966; Ziller, Behringer, & Goodchilds, 1962). These studies all used complex tasks or studied work that involved creativity and innovation. For example, Wells and Pelz (1966) analyzed the performance of groups of scientists and engineers while Virany et al. (1992) studied executives in the computer industry. The work of scientists, engineers, and executives is more complex and more subject to innovation than, for example, work performed by direct production workers in bureaucratic organizations. Due to innovations that occur in the performance of complex tasks, knowledge of incumbents may become obsolete. Thus, their departures may not be costly since much of their knowledge may no longer be relevant for task performance. By contrast, newcomers may be more up-to-date and possess expertise relevant for the task. This theoretical argument leads one to predict that turnover would have a less negative (or even positive) effect on the performance of complex than of simple tasks.

Results indicated that group performance improved significantly as experience was gained with the task. Groups that did not experience turnover produced significantly more products than groups that experienced turnover and this difference was amplified over time. That is, the gap between the performance of groups that experienced turnover and those that did not widened over time. Groups produced more of the simple than the complex product, and this difference was also amplified over time. The gap in the performance of no-turnover versus turnover groups increased over time, and the increase in the gap was greater for the simple than for the complex task. Thus, while all groups were hurt by turnover, it had less impact on the complex than on the simple task. Based on analyses of innovations generated in the experiment, we suggested that the lesser impact of turnover on the complex tasks was due to the greater frequency of innovations that occurred on the complex task. The departure of experienced group members appeared less costly on the complex tasks because some of their knowledge was no longer relevant due to technological innovations.

The effect of turnover has also been found to depend on the quality of replacements and on the extent to which turnover is anticipated. Trow (1960) investigated the effect of turnover on performance in a laboratory study that employed the common symbol task. Trow found that turnover was not disruptive when replacements had experience with the task, were at least as competent as their predecessors, and the group had previous experience with the same rate of turnover.

Although these studies of the effect of turnover have primarily focused on turnover of workers engaged in direct production activities, a few studies have examined the effect of executive turnover on organizational learning. Virany et al. (1992) examined turnover of executives as a mechanism for organizational learning and adaptation in a study of minicomputer firms. The researchers suggested that executive change facilitates learning and adaptation by changing the knowledge base and communication processes of the executive team. Their results indicated that turnover of the chief executive officer and turnover in the executive team were positively associated with organizational performance. Thus, in the turbulent minicomputer industry, executive change may have served as a means for bringing in new knowledge and relevant expertise.

Similarly, in their study of the cement industry, Tushman and Rosenkopf (1996) found that executive succession alone was positively associated with subsequent firm performance in stable contexts and negatively associated in turbulent contexts. A more complex picture emerged for executive team change. Departures of executive team members (exits) had different effects than arrivals of new members (entries). In turbulent contexts, executive team entries were more positively associated with subsequent performance, whereas executive team exits were more negatively associated with subsequent performance. The researchers suggested that when environments shift and the locus of the crisis is outside the firm, organizational performance is strengthened by bringing in new executive team expertise while retaining existing expertise. By contrast, when the source of the crisis is within the firm, executive team exits were more positively associated with organizational performance.

These results are more complex than those of the Virany et al. (1992) study in the minicomputer industry. The results suggest that turnover in the executive team has different effects than turnover of the top executive and further that entries and exits of executive team members have differential effects on performance. Comparing the two studies, it is interesting to note that it is in the more stable cement industry that one finds some benefits of retaining existing knowledge and expertise, while in the more turbulent computer industry, turnover at the executive level was more uniformly associated with performance improvements. These results are generally consistent with the Argote et al. (1995) study. Turnover is less harmful—and may even be beneficial—on complex tasks that involve change and innovation.

Taken together, these studies of turnover and organizational learning suggest conditions under which turnover is likely to have a significant effect on organizational learning. Turnover of individuals interacts with other knowledge repositories to determine its effects on organizational learning and forgetting. Results indicate that turnover affects performance gains from experience most when (1) departing members are exceptional performers (e.g., see Argote et al., 1997); or (2) replacements have less experience or less competence than departing members (Trow, 1960); or (3) departing members occupy structural holes (Shaw et al., 2005); or (4) the organization uses few rules and routines (Rao & Argote, 2006; Ton & Huckman, 2008); or (5) the organization is low in hierarchy (Carley, 1992); or (6) the task does not involve innovation (Argote et al., 1995). Although turnover of high-performing direct production workers in a manufacturing plant negatively affected the plant's productivity, turnover of executives in the minicomputer industry had a positive effect on performance. The former effect may have reflected the cost of the loss of individuals who had critical knowledge embedded in them while the latter may have reflected the benefit of incorporating individuals with new knowledge into the organizations.

4.3.2 Knowledge Embedded in Organizations

We turn now to evaluating empirical evidence on the extent to which knowledge is embedded in organizations. Knowledge embedded in an organization is harder to measure and analyze than knowledge embedded in individuals. An interesting naturally occurring experiment provided an opportunity for us to analyze the extent to which knowledge acquired through learning by doing became embedded in the organization versus in individual employees (Epple, Argote, & Murphy, 1996). Although the natural experiment did not enable us to further disentangle in which component of the organization knowledge was embedded, the study was informative about whether knowledge was embedded in individuals versus in the organization.

A manufacturing plant added a second shift almost 2 years after the first shift had been in operation (Epple et al., 1996). The second shift used the same technology and was embedded in the same structure as the first shift but was composed of predominantly new employees. Thus, comparing the performance of the second to the first shift provides an indicator of the extent to which knowledge was embedded in the organization's structure and technology versus in individual workers. If the learning curve on the second shift followed the same pattern as the first shift's curve had, it suggests that knowledge is embedded primarily in individual workers because workers on each shift went through the same learning process. Alternatively, if the second shift learns faster than the first, it suggests that knowledge acquired from the start of production by the first shift was embedded in the organization and led to improvements in the performance of the second shift. To investigate this issue, we analyzed the transfer of knowledge that occurred from the period of operating with one shift to the period of operating with two shifts and the ongoing transfer of knowledge between the two shifts once they were both in operation (see Epple, Argote, & Devadas, 1991, for development of the method).

Our results indicated that knowledge acquired during the period of operating with one shift carried forward quite rapidly to both shifts of the two-shift period. The second shift was composed predominantly of new employees. The second shift achieved a level of productivity in 2 weeks that it had taken the first shift many months to achieve. This suggests that knowledge acquired during the period of one-shift operation had been embedded in the organization. The second shift did not have to go through the long learning period that the first shift had. The second shift benefited from the knowledge acquired by the first shift that had been embedded in the organization (i.e., its technology, structure, routines, or layout). This knowledge improved the second shift's performance.

As noted previously, this study did not enable us to disentangle the effect of knowledge embedded in the organization's technology from the knowledge embedded in its structure. Both contributed to the ability of the second shift to achieve a high level of productivity so rapidly. Our sense from observing the plant and the interviews we conducted there was that more of the action occurred on the technological than on the structural dimension. While some structural modifications were made, enormous changes occurred in the plant's layout and its technology as it gained experience in production. The studies described in the following sections enable one to determine somewhat more clearly whether knowledge was embedded in the organization's technology or its structure.

4.3.2.1 Knowledge Embedded in Tools and the Tool–Tool Network

Studies of technology transfer shed light on the extent to which knowledge is embedded in tools. These studies typically examine how technology developed at one site transfers to another and the conditions that facilitate or impede such transfer (e.g., Allen, 1977; Ounjian & Carne, 1987). A relevant study that is particularly compelling for the goals of this book is one that included productivity as the dependent measure and analyzed the effects of various factors on how long it took a "recipient" site to reach the level of productivity a "donor" site had achieved (Galbraith, 1990). Galbraith (1990) studied 32 attempts to transfer technology internally from one site to another within the same organization. The results of the Galbraith study illustrate both the difficulty of transferring technology and the savings in productivity that can occur from successful technology transfer attempts. For the 32 technology transfer attempts, the initial productivity at the recipient site after the technology was transferred averaged 34 % less than what the donor site had achieved at the time of transfer. The productivity loss ranged from a low of 4 % to a high of 150 %. Thus, some of the recipient organizations almost instantaneously achieved a level of productivity that it had taken the donor sites months or even years to achieve, whereas other recipient sites did not even approach the productivity of the donor sites after the transfer. Indeed, 10 of the 32 technology transfer attempts were considered failures because they never reached the level of productivity of the donor site prior to the transfer.

The Galbraith results tell a story that is both "half-full" and "half-empty" from the perspective of knowledge embedded in technology. On the positive side, the results illustrate that some organizations can achieve remarkable productivity gains by transferring technology. These organizations are able to embed knowledge in technology and successfully transfer the knowledge to a new site. For other organizations, however, the results are less satisfying. Their attempts to embed knowledge in technology and transfer it to another site do not result in large productivity gains at the recipient organization. Factors that facilitate the successful transfer of technology are discussed in Chap. 6 on knowledge transfer.

Information systems can serve as knowledge repositories. Alavi and Leidner (2001) suggested that computer storage and retrieval tools enhance organizational memory. Ashworth, Mukhopadhyay, and Argote (2004) found that the introduction of a new information system at a financial services firm reduced knowledge depreciation.

4.3.2.2 Knowledge Embedded in the Task–Task Network

Researchers have also analyzed the extent to which knowledge acquired through learning by doing is embedded in routines, a task–task network. Cohen and Bacdayan (1994) demonstrated that knowledge acquired through task performance can be embedded in supra-individual routines. Based on empirical evidence from a laboratory study of dyads playing a card game, the researchers concluded that the behavior of the dyads was indicative of the operation of routines. In particular, the performance of the dyads became faster and more reliable over time. Different dyads evolved different routines that were stable over time (see also Weick & Gilfillan, 1971). And dyads persisted in using their idiosyncratic routines, even when more effective routines existed.

Further, Cohen and Bacdayan (1994) found that task performance slowed down significantly with the introduction of novelty in the experiment but not with an increase in time delay. The researchers argued that this pattern provided further evidence of the operation of routines. Delay should not affect routinized task performance because routines are stored as procedural memory that exhibits little decay, whereas novelty should affect routinized task performance because novelty causes subjects to switch to slower declarative processing (Singley & Anderson, 1989).

As noted previously, routines have been studied as a factor that conditions the effect of turnover on outcomes. Rao and Argote (2006) found in a laboratory study that relying on routines reduced the negative effects of turnover. Similarly, Ton and Huckman (2008) found in a field study that organizations that relied on processes and routines were less affected by turnover than those that did not.

Moorman and Miner (1998) developed propositions about the effects of procedural and declarative knowledge on organizational improvisation, the convergence of composition and execution in time. The researchers argued that procedural memory would increase the speed but reduce the novelty of improvisational activity. By contrast, declarative memory was hypothesized to reduce the speed but increase the novelty of improvisation.

4.3.2.3 Knowledge Embedded in the Member–Member Network

The member–member network has been investigated as a factor that moderates the effect of turnover on organizational learning and forgetting. For example, hierarchical networks have been found to buffer organizations from the effects of turnover (Carley, 1992). Examining the effect of the departing member's position in a network, Shaw et al. (2005) found that turnover of members who occupied structural holes was more harmful than turnover of members in dense networks.

4.3.2.4 Knowledge Embedded in the Member–Task, Member–Tool, and Task–Tool Networks

Research on "transactive memory" (Wegner, 1986, 1995) is relevant for understanding knowledge embedded in networks including the member–task, member–tool, and member–task–tool network. Transactive memory research emphasizes that as social systems gain experience, members acquire knowledge about which member is good at performing which task or operating which tool. Recently, researchers have extended transactive memory research to include the task–tool network. Sparrow, Liu, and Wegner (2011) found that participants thought of computers when they needed to find information and were better able to remember where information was stored than the information itself. The researchers argued that the Internet, a tool, has become a component of many individual's transactive memory systems.

Consider an example of how a transactive memory system might work. A group of research collaborators might learn that one member of the team is particularly good at experimental design, while another excels at data analysis, and a third is a very strong writer. As the group gains experience and learns who is good at what, it specializes and assigns tasks to the individual with the most skill and expertise. That is, as group members work together, they learn who has a deeper understanding of statistics and rely more on that person for dealing with statistical concerns. As group members read each other's writing, members also learn who the most gifted writer is. That person is likely to take on more of the group's writing tasks. Furthermore, as group members see the consequences of various design choices, members acquire information about who has the best instincts about the design of research studies. This knowledge of who knows what facilitates matching of tasks to individuals' skills and expertise. Individuals' meta-knowledge of who knows what in the group allows them access to a much larger knowledge base than their own. Individuals learn whom to go to if they have a question or need advice. Group members also learn how to communicate and coordinate effectively with one another, perhaps by developing special terms and customs. Members also learn whom they can trust. The transactive memory system the group develops facilitates its performance.

My colleagues and I used Wegner's concept of transactive memory to investigate the effects of training methods on group performance (Liang, Moreland, & Argote, 1995). In an initial study, we compared the performance of groups whose members were trained individually to that of groups whose members were trained together on a production task, assembling a radio. Groups whose members were trained together recalled more about the task and made fewer errors than groups whose members were trained apart. The superior performance of groups in the group training condition seemed to stem from the operation of a transactive memory system. Groups whose members were trained together exhibited greater specialization or memory differentiation, trusted each others expertise more, and coordinated better than groups whose members were trained individually. Further, the transactive memory system mediated the relationship between training and group performance (Baron & Kenny, 1986): when the degree to which the groups developed transactive memory systems was taken into account, training methods no longer mattered. Thus, the superior performance of groups who received training together was due to the operation of transactive memory systems.

A subsequent study replicated the first and included two additional conditions (see Moreland, Argote, & Krishnan, 1996). One condition in which participants were trained as individuals and then given a team-building exercise was added to investigate further whether the superior performance of participants trained as a group was due to enhanced group development. The performance of participants in this individual training plus team-building condition was inferior to that of participants trained as a group and comparable to that of participants who received only individual training. This finding enabled us to rule out the hypothesis that enhanced group development led to the superior performance of participants who were trained together. Providing groups an opportunity to interact was not sufficient to improve their performance.

Another condition was added to the second study in which participants were trained in one group and performed in another. The performance of participants who were trained in this condition was comparable to the performance of participants in the individual training condition and the individual training plus team-building condition, and inferior to that of participants who trained and performed in the same group. Thus, it is not experience in working with any group that leads to superior performance, but experience in working with particular group members that allows for the development of knowledge of who is good at what and leads to the creation of a transactive memory system. It is the transactive memory system that drives group performance.

A third study measured more directly what members of a group learned as they gained experience (Moreland, Argote, & Krishnan, 1998). To assess whether group members who trained together would know more about one another than those trained apart, participants were asked to complete a questionnaire after they received training and before they took part in the second experimental session. The questionnaire measured what the members of each group knew about each other's expertise. Participants who were trained together wrote more complex analyses of each other's strengths and weaknesses. To assess the accuracy of these perceptions of each other's strengths and weaknesses, the questionnaire data were compared to objective information about performance on the radio assembly task. Results indicated that participants who were trained together had more accurate perceptions of each other's expertise than participants who were trained individually. Further, members of groups who were trained together agreed more about each other's strengths and weaknesses than members trained apart.

Another goal of the third experiment was to determine if social loafing and free riding (see Karau & Williams, 1993) affected performance in the various training conditions. Training members of a group together could lead to social loafing: some group members may not learn the task very well because they expect to be able to rely on others. During the first experimental session of this study, participants were trained either individually or in a group, as in previous studies. When they returned for the second experimental session, however, all participants were asked to perform the task *individually*. This enabled us to determine whether participants who were trained in a group learned the task as well as subjects who received individual training. Results indicated that there were no significant differences in *individual* performance between participants who were trained individually and those who were trained as a group. Although further research is needed to rule out the possibility of social loafing in group training, our results suggest that individual learning occurs to about the same degree whether participants are trained individually or in a group. Thus, social loafing does not seem to be a serious problem here.

Hollingshead (1998) also compared the effect of group and individual training on group and individual performance for a different task: collective induction. Results indicated that group performance was facilitated by previous practice as a group and not by practice as individuals. Individual performance, however, was not affected by either individual or group practice. These results obtained on collective induction tasks are very similar to those already described for the radio production task.

Hollenbeck et al. (1995) also found that experience improved group performance in a study of hierarchical teams. Much (albeit not all) of the effect of experience on performance was mediated by its effect on three core variables (1) the degree to which the team was informed about the decision; (2) the extent to which members' judgments were accurate, and (3) the degree to which the leader gave appropriate weights to group members' judgments. This last factor is similar to a dimension of transactive memory—knowing who is good at what and weighting their contributions accordingly. In a second study, Hollenbeck et al. (1995) found that teams that had an incompetent member and those low in cohesiveness performed more poorly than their counterparts. Similar to the previous results, much (but not all) of the effect of cohesion and competence on decision accuracy was mediated by the three core variables.

These laboratory studies of small groups relate to information we obtained from interviewing and observing managers at manufacturing facilities. As noted previously, when we interviewed managers about what accounts for organizational learning curve, they emphasized the importance of learning who was good at what and assigning tasks accordingly. Thus, these organizations were developing transactive memory systems—knowledge of who was good at what—and using this knowledge in task distribution and performance.

The concept of transactive memory has been extended to the organizational level and expanded to include knowledge of the capabilities of other organizations as well as knowledge of the capabilities of one's own organization. Rulke, Zaheer, and

Anderson (2000) developed and collected fine-grained measures of the knowledge retail food organizations possessed about their own capabilities and the capabilities of other firms. The researchers examined the relationship between these two types of knowledge (self-knowledge and knowledge of others) and objective measures of performance, such as sales per square foot. Results indicated that both types of knowledge contributed significantly to firm performance. Further, a significant interaction was found between the two knowledge variables that indicated that firms with high self-knowledge did not benefit as much from knowledge of the capabilities of others as those with low self-knowledge. The Rulke et al. (2000) study is particularly exciting because it demonstrates the importance of transactive memory in a field setting and shows the link between transactive memory and objective indicators of firm performance.

Since the early laboratory studies of transactive memory, the concept has also been investigated in the field (Austin, 2003; Faraj & Sproull, 2000; Lewis, 2004). Many studies have found that groups with well-developed transactive memories perform better than those with less developed transactive memories. Although most studies have examined outcomes such as the quality and speed of performance, research has also found that transactive memory systems enhanced creativity (Gino, Argote, Miron-Spektor, & Todorova, 2010). Simulation results have shown that transactive memory systems are especially valuable under changing conditions (Ren, Carley, & Argote, 2006).

Experience working together is one of the strongest predictors of the development of transactive memory systems. Thus, as members work together on the same or related tasks, they learn who is good at what. Other factors shown to affect the development of transactive memory systems include communication (Hollingshead & Brandon, 2003; Lewis, 2004), interdependence (Hollingshead, 2001; Zhang, Hempel, Han, & Tjosvold, 2007), and stress (Pearsall, Ellis, & Stein, 2009). Reviews of the literature on transactive memory can be found in Peltokorpi (2008) and Ren and Argote (2011).

4.4 Consequences of Where Knowledge Is Embedded

Although empirical work on organizational learning and memory has increased in recent years (Miner & Mezias, 1996), there is little empirical evidence about the consequences of where knowledge is embedded for aspects of organizational performance. We are just beginning to understand the effect of organizational memory on organizational outcomes. An empirical study that directly examined the effect of memory on dimensions of organizational performance found that organizational memory affected the new product development process by influencing both the interpretation of new information and the performance of new routines (Moorman & Miner, 1997). Results indicated that higher organizational memory levels enhanced the short-term financial performance of new products, while greater memory dispersion increased both the performance and creativity of new products.

Results also indicated that high memory dispersion could detract from creativity under conditions of environmental turbulence.

In this section, I draw on related literature and qualitative work we have done in franchise organizations (Argote & Darr, 2000) to suggest how where knowledge is embedded affects its persistence and transfer in organizations. Research on knowledge transfer is briefly discussed here because the transfer of knowledge from one unit to another provides evidence of its persistence. The following sections suggest how embedding knowledge in individuals, in tools, in routines, and in transactive memory systems affects its persistence over time and its transfer to other organizational units.

4.4.1 Knowledge Embedded in Individual Members

Individuals provide both a sensitive and a precarious way of storing, maintaining, and transferring knowledge. Individuals are capable of capturing subtle nuances that other repositories are not able to store as readily. For example, in a series of ingenuous experiments, Berry and Broadbent (1984, 1987) showed that although individuals improved their performance as they gained experience with a task, they were not able to articulate what strategies they had used or why their performance had improved. Thus, as they gained experience with the task, individuals acquired tacit knowledge that they were not able to articulate to others. Individuals were able, however, to transfer their tacit knowledge to another similar task. When participants in the experiments performed a second task, the performance of those with previous experience on a similar task was significantly better than that of participants without any previous experience. Thus, even though participants could not articulate why their performance improved, they were able to transfer the knowledge that enabled them to improve their performance to a similar task.

These results suggest that moving personnel is a very effective way to transfer knowledge in organizations because individuals can transfer their tacit knowledge to other tasks and contexts. Thus, by transferring personnel, one transfers the tacit knowledge that individuals carry with them. Most studies of technology transfer find that moving personnel is a powerful facilitator of knowledge transfer (e.g., see Galbraith, 1990; Rothwell, 1978). A benefit of personnel movement is that it allows individuals to transfer their tacit knowledge to new contexts.

An alternative way of transferring tacit knowledge is to convert it to explicit knowledge. Nonaka (1991) described a fascinating example of how an engineer apprenticed herself to a bread maker to acquire the bread maker's tacit knowledge. Through a long period of observation of the bread maker, the engineer captured the bread maker's tacit knowledge and converted it to explicit knowledge. This explicit knowledge served as the base for Matsushita's bread-making machine.

Individuals are the most effective media for acquiring and storing tacit knowledge. They are also an effective media for transferring tacit knowledge. Individuals can apply their tacit knowledge to a new task or a new context without converting their tacit knowledge to explicit knowledge. Alternatively, through a lengthy period of observation and apprenticeship, others may be able to capture an expert's tacit knowledge and convert it to explicit knowledge that others can access.

Without moving personnel or explicitly attempting to capture their knowledge, knowledge embedded in individuals will generally not transfer. Qualitative results from our study of fast-food franchises illustrate how knowledge embedded in individuals generally does not transfer to new sites. In our study of fast-food franchises, we observed 14 innovations at the stores (Argote & Darr, 2000). Of the 14 innovations that occurred in the fast-food franchises, 6 were embedded in individuals. For example, knowledge about how to hand-toss pizza remained embedded in individual workers. Knowledge about how to prioritize pizzas so as to take advantage of cooking time differences across pizza types and sizes and, thus, make better use of the oven also remained embedded in a few individual order-takers. Of the six innovations that were embedded in individuals, only two transferred outside the store of origin. By contrast, both of the innovations embedded in technology transferred outside the store of origin and five of the six innovations embedded in routines transferred outside the store of origin. Thus, knowledge embedded in individuals does not transfer as readily outside the organization of origin as knowledge embedded in technology or routines does.

Several pitfalls are associated with relying on individuals as a knowledge repository for organizations. Knowledge embedded in individuals may decay or depreciate faster than knowledge embedded in social systems. The results of an interesting laboratory study that compared individual and group recall suggest that knowledge embedded in groups is more stable than knowledge embedded in individuals (Weldon & Bellinger, 1997). The researchers found a tendency for groups to exhibit less forgetting than individuals. Further, the organization of group recall was more consistent over trials than the organization of individual recall. Thus, an important difference between collective and individual memories may be the relative stability of collective memories. Knowledge embedded in the group or social system seems to be more stable than knowledge embedded in individuals, even when there is no turnover of those individuals.

Another downside of relying on individuals as a knowledge repository is that individuals may not be motivated to share their knowledge. The Engeström et al. (1990) example discussed earlier in which an individual hoarded knowledge and did not share it with others is an example of this phenomenon. Many studies have shown that individuals typically do not share information that they uniquely hold (e.g., see Stasser & Titus, 1985).

A third downside of relying on individuals as a knowledge repository for organizations is that individuals can leave and take their knowledge with them. Conditions under which individual turnover will be especially harmful for organizations were discussed earlier in this chapter. Organizations can use a variety of strategies for capturing individual knowledge. Embedding individual knowledge in organizational structures and routines is a productive way to mitigate the effect of individual turnover (Rao & Argote, 2006). Similarly, organizations may try to capture the knowledge of individuals and embed it in technology such as information systems and knowledge networks (Moreland, 1999; Stewart, 1995a, 1995b).

A significant component of individual knowledge, however, such as tacit knowledge, may be less amenable to being embedded in organizational structures and technologies. For organizations with a large component of tacit knowledge, attempts to bond the individual to the organization may be more fruitful than attempts to embed the knowledge in structures and technologies. Starbuck (1992) described the strategies organizations such as law firms and consulting firms use to prevent individuals from leaving. In these organizations, where much of the knowledge is embedded in individuals, their turnover would be very harmful for the organization's performance. Hence, contracts are written and incentives are developed to motivate key individuals to remain with the firm.

A fourth disadvantage of relying on individuals to transfer knowledge is that it is hard for individuals to reach a large number of people without some degradation in the communication. Thus, for large organizations where reliability is important, it will not be efficient or effective to rely on individuals as the primary means for transferring knowledge. Individuals can be used effectively to complement other repositories, but relying solely on individuals to transfer knowledge in these settings will not be effective.

4.4.2 *Knowledge Embedded in Tools and the Tool–Tool Network*

Technology is a very effective repository for retaining explicit knowledge. As noted in the discussion of organizational forgetting in Chap. 3, we observed the least depreciation of knowledge in technologically sophisticated organizations. While more research is needed to determine whether it is technological sophistication that drives these organizations' ability to retain knowledge, the depreciation rates observed across a variety of settings are consistent with the hypothesis that embedding knowledge in technology is an effective way to mitigate its depreciation. Similarly, Smunt (1987) suggested that embedding knowledge in technology is an effective way to prevent organizational forgetting. While embedding knowledge in technology does not guarantee its persistence, it makes persistence more likely.

Embedding knowledge in technology is also an effective way of transferring knowledge to other sites. Two of the innovations we observed in our study of fast-food franchises were embedded in technology. The "cheese spreader" example discussed earlier in this chapter is an example of one of these innovations. Both of the innovations embedded in technology transferred outside the store of origin. While the number of innovations embedded in technology was, of course, too small to permit firm conclusions, the results are suggestive of the effectiveness of technology as a medium for transferring knowledge.

The results of our study of knowledge transfer across shifts in a manufacturing facility also illustrate the effectiveness of technology as a mechanism for transferring organizational knowledge. The technology-transfer literature provides further evidence that embedding knowledge in technology and transferring it to another site can result in substantial savings for the recipient organization.

Interestingly, transferring knowledge by embedding it in technology is often most successful when it is accompanied by transferring a few individuals as well (e.g., see Galbraith, 1990; Rothwell, 1978). The advantages of individuals as knowledge repositories complement those of technology. Individuals capture the tacit knowledge, the subtlety, and the understanding behind the technology. By contrast, technology provides consistency and reliability and reaches a large scale.

A cost of embedding knowledge in technology is that the knowledge may become obsolete yet be more resistant to change because it is embedded in "hard" form. Abernathy and Wayne's (1974) analysis of Ford's production of the Model T suggested that Ford's investment in "hard" automation to produce the Model T made it more difficult for Ford to change to meet customer preferences and offer a more varied product line. This example illustrates potential disadvantages of embedding knowledge in technology: increased rigidity and resistance to change. Today's technologies are generally more flexible than they were in the 1920s, so the downside potential of embedding knowledge in technology might now be somewhat less. Nonetheless, rigidity associated with embedding knowledge in hard form is an important potential cost of embedding knowledge in technology that should be considered.

Knowledge management systems have been advocated as a knowledge repository that captures knowledge from the past to inform future decisions. Evidence on the effectiveness of these systems, however, is mixed. Haas and Hansen (2005) studied a consulting firm that used a knowledge management system consisting of document libraries linked by a search engine. The researchers found that the performance of consulting teams was negatively associated with the number of documents they used from the system. Further, using documents from a knowledge management system was especially harmful for experienced teams and teams facing very competitive environments.

By contrast, Kim (2008) found that the effect of using a knowledge management system in a chain of retail grocery stores was generally positive. The impact of the knowledge management system on performance was more positive for managers with fewer alternative sources of knowledge, for managers in remote locations, and for managers of products that did not become obsolete quickly.

The difference in the effectiveness of these two knowledge management systems seems likely due to task differences between the two contexts. Arguably, the problems encountered by managers in a retail grocery team were more similar and less novel than those faced by consulting teams. The document repository form of knowledge management system appears to be more effective in organizations facing recurring tasks that are similar than in those facing varied and novel tasks.

4.4.3 *Knowledge Embedded in the Task–Task Network*

Routines, elements of the task–task network, are effective mechanisms for storing and maintaining knowledge. For example, in our study of fast-food franchises, we saw an example of a very efficient and effective routine for placing pepperoni on pizza. As described previously, it was discovered that placing pepperoni in a pattern that resembled spokes on a wheel before deep-dish pizza was cooked resulted in an even distribution of pepperoni on the cooked pizza. The discovery was embodied in a routine that could be used easily by all pizza makers. Embedding the knowledge in a routine made it more resistant to employee turnover. If the individual who made the discovery of how to achieve an even distribution departed from the store, the knowledge would remain in the organization. Embedding knowledge in a routine enhances persistence.

Routines, elements of the task–task network, are also an effective mechanism for transferring knowledge to other organizations. The routine for placing pepperoni was discovered in a store in Southwestern Pennsylvania. The routine transferred very quickly to other stores in the same franchise. A consultant from the parent corporation who saw the routine on a visit to one of the stores was impressed by the routine's effectiveness and diffused it widely to stores throughout the corporation. The routine is now used in nearly all of the stores of the parent corporation.

Indeed, other routines we observed in the fast-food franchise study also transferred outside the store of origin. Of the 14 innovations we identified in our fast-food franchise study, 6 were embedded in routines. Of these six, five transferred outside the store of origin. And three of those transferred to stores in different franchises. Thus, embedding knowledge in a routine is an effective way to facilitate knowledge transfer.

The results of a study by Zander and Kogut (1995) are consistent with our qualitative results regarding knowledge transfer. Zander and Kogut (1995) examined factors affecting the speed of transfer of manufacturing capabilities. The researchers found that capabilities that could be codified (e.g., in documents or software) transferred more readily than capabilities not easily codified. In order to be embedded in a routine, capabilities must be codified.

A downside of relying on routines is that they may be used inappropriately. Researchers have written about the importance of "unlearning" in organizations—forgetting the old and developing a better, more appropriate routine as a way of adapting to changed circumstances (e.g., Hedberg, 1981). Unlearning is arguably an example of learning—of developing a more elaborate response repertoire that specifies the conditions under which various responses are appropriate. So rather than "forget" a routine used in the past, it would be preferable to remember the routine, the conditions under which it worked, and why it is no longer successful. Thus, lessons of the past can be applied to the present to facilitate organizational performance.

4.4.4 *Knowledge Embedded in the Member–Task Network*

Several studies have examined the persistence of knowledge in transactive memory systems. Research has shown that knowledge embedded in transactive memory systems persists more than knowledge embedded in individual members. In a series of studies, researchers compared the recall 1 week after the training of groups whose members were trained together to the recall of groups who members were trained apart (Liang et al., 1995; Moreland et al., 1996). Groups trained together recalled more 1 week later than groups whose members were trained apart. The greater recall of group-trained groups relative to individually trained groups could be explained by their more developed transactive memory system (Liang et al., 1995).

Studies have examined how resilient knowledge embedded in transactive memory systems is to member turnover. If turnover from one period to the next is complete such that no individual worked with someone they had previously, then the transactive memory formed from working together is no longer relevant and confers no benefits for task performance (Moreland et al., 1996). If turnover is not complete and a subset of members continue to work together, transactive memory systems can retain value (Lewis, Belliveau, Herndon, & Keller, 2007). The effectiveness of transactive memory systems depends on contingencies, such as the extent to which the skills of new members are similar to those of departed members.

4.5 Conclusion

The chapter began with a discussion of examples of productivity-enhancing improvements that occurred as organizations gained experience in production. These improvements were mapped onto theoretical discussions of organizational memory. A framework of members, tasks, tools, and their networks was used to characterize repositories of organizational memory. Empirical evidence on the effect of embedding knowledge in these three repositories was reviewed. Considerable research has been done on the effect of embedding knowledge in individuals. Some research has been done on the effects of embedding knowledge in tools, in task–task sequences or routines, and in member–task networks or transactive memory systems. More research is needed on knowledge embedded in these repositories as well as in the member–member or social network. The chapter concluded with a discussion of the implications of where knowledge was embedded for organizational performance. Individuals are capable of capturing and transferring subtle nuances and tacit knowledge. By contrast, organizational routines and technologies are less "sensitive" repositories. Knowledge embedded in organizational routines and technologies, however, is more resistant to depreciation and more readily transferred than knowledge embedded in individuals. Organizations can use the strengths of one knowledge repository to offset the weaknesses of another.

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