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ABSTRACT

This document contains three papers from a symposium on technological change and human resource development. "New Technologies, Cognitive Demands, and the Implications for Learning Theory" (Richard J. Torraco) identifies four specific characteristics of the tasks involved in using new technologies (contingent versus deterministic tasks, distancing technologies, stochastic events, and systemic interdependence) and examines the extent to which the theories of Scribner, Schon, Wenger, and Hutchins are capable of explaining human cognition and learning as they relate to the use of new technologies. "A Study of Technology Transfer for Thai Workers in Thailand" (Palapan Kampan, Boon-Anan Phinaitrup) reports on a study in which a total of 350 human resource managers, Thai workers, foreign workers, and institution administrators were surveyed to gain insight on the process of the transfer of technology from foreign workers to Thai workers in Thailand's manufacturing sector. "Impact of Technological Change on Human Resource Development Practices: A Study of Singapore-Based Companies" (A. Ahad Osman-Gani, Ronald L. Jacobs) presents a study of 908 randomly selected Singapore-based companies that explored the impact of technological changes on the companies' training and development practices, resistance to technological changes, and sectoral patterns in using training and development strategies to cope with technological change. The first two papers include substantial bibliographies. (MN)

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New Technologies, Cognitive Demands and the Implications for Learning Theory

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The cognitive demands of new technologies are poorly understood for many reasons. This paper identifies the cognitive demands of tasks involving the use of new technologies. The paper examines how well theories of learning address these cognitive demands. Four theories—those of Scribner, Schon, Wenger, and Hutchins—are analyzed for their power to explain human cognition and learning as they relate to the use of new technologies. Finally, the implications of this study for further research on theory building and the role of technology in augmenting human performance are discussed.

Keywords: Theory Building, Cognitive Demands, Learning Theories

New technologies have been shown to place unique cognitive demands on those who use them. Four specific characteristics of tasks involving the use of new technologies have been identified. They are *contingent versus deterministic tasks, distancing technologies, stochastic events*, and *systemic interdependence.*

- *Contingent versus deterministic tasks.* When applied to what were once routine, predictable tasks *(deterministic tasks)*, new technologies have substantially increased the contingency of these tasks by reducing their transparency and increasing their speed. Technicians and customers can no longer see the flow of information and materials and must infer from outputs what occurred earlier in the work process (Pentland, 1997).
- *Distancing technologies* such as digital displays, controls, and sensor technologies, remove the operator from the operating location and eliminate the physical cues and sentient information from which knowledge can be derived (Woods, O'Brien, and Hanes, 1987; Zuboff, 1988).
- *Stochastic events* are randomly occurring and unpredictable events that are properties of new technologies (Weick, 1990) and flexible manufacturing systems (Norros, 1996). Dealing with the disruptions from new technologies increases the cognitive demands placed on technicians who must use them.
- *Systemic interdependence* is the system of relationships needed to assure that one's work is coordinated with the work of others (Adler, 1986).

Each of these task characteristics places unique cognitive demands on those who use new technologies. The cognitive demands of these task characteristics are discussed next and summarized in Table 1. (See Table 1., *The Cognitive Demands of Task Characteristics*).

Table 1. *The Cognitive Demands of Task Characteristics*

Task Characteristics	Cognitive Demands
Contingent versus Deterministic Tasks	• Mental reconstruction of problem and causes • Capability for systematic search and pragmatic solutions • Ability to go beyond scripted procedures
Distancing Technologies	• Capabilities for inference, imagination, and mental modeling to understand what is going on elsewhere • Reconciliation of mental representation of work process with actual work process
Stochastic Events	• Movement from emotional arousal to constructive thought and action • Memory (information storage and retrieval) to reconsider means-ends relationships and desired end-states • Improvisation—the abilities of the bricoleur
Systemic Interdependence	• Interpersonal skills • Transactive memory

Cognitive demands of contingent tasks. New technologies have substantially increased task contingency by reducing their transparency, increasing their speed, and expanding the menu of options available for task accomplishment. Work processes that were formerly separate and observable have been combined through process engineering (Davenport, 1993) and have disappeared into computer-controlled machines and communication technology (Weick, 1990). Technicians and customers can no longer see the flow of information and materials and must infer from outputs what occurred earlier in the work process. New technology also feeds social pressures for rapid transactions, especially in customer service situations. Pre-determined procedures are frequently abandoned to expedite customer requests. As witnessed in equipment repair (Orr, 1996), software support (Pentland, 1997), science laboratories (Barley and Bechky, 1994), insurance claim processing (Wenger, 1999), automobile assembly (Graham, 1993), and military operations (Weick and Roberts, 1993; Hutchins, 1995), new technologies have made technical tasks more contingent than ever.

Since technical work is filled with novel or poorly defined problems that cannot be fully anticipated in advance (Barley and Orr, 1997), technicians are often confronted by technology breakdowns of ambiguous origins that cannot be resolved with schematics and procedural knowledge alone. Since their problem-solving algorithms are inadequate for the variety and unpredictability of these problems, technicians must rely instead on pragmatic rules of thumb and other shorts cuts afforded by the task environment. To understand and respond to ambiguous situations, workers must make use of improvised materials, local conditions, and social circumstances, thus deploying contingent work strategies that reflect the changing properties of the task environment.

Cognitive demands of distancing technologies. Distancing technologies are present in work environments ranging from industrial factories (Zuboff, 1988) to high technology settings (Pentland, 1997). Digital displays, controls, and sensor technologies at the operator's workstation are symbolic representations that distance workers from the physical and sensory referents present at the actual sites of operation. In the pulp and paper mills studied by Zuboff, instrumentation formerly was located on or close to the operating equipment, allowing the operator to combine data from an instrument reading with data from his or her own senses. *Distancing technologies* removed the operator from the operating location and eliminated the physical cues and sentient information in which knowledge was based. The problems created by physical distance are magnified by the computer controls of most distancing technologies that display indicators on separate screens of a computer monitor. To recognize irregular patterns among the data or to initiate novel search sequences, the technician must remember what earlier screens have shown and hope that the readings have not changed while subsequent screens are accessed. However, human factors research has shown that it is easier to recognize patterns when data are presented simultaneously rather than serially. Technicians in production control rooms who use this technology can easily create novel search sequences when they are able to sweep visually across an array of dials that present data at the lowest level of detail (Woods, O'Brien, and Hanes, 1987).

Separation from the operating environment requires workers to interpret symbolic, electronically-presented data. This increases cognitive demands to understand what is going on at remote operating sites. Software support technicians and production control room operators have to imagine the conditions in the operating environment that cannot be displayed by their information systems. Before attempting to solve problems, they must first mentally visualize the conditions the give rise to the problems. Thus, the physical and psychological separation created by distancing technologies increases cognitive demands for inference, imagination, and mental modeling to understand what is happening elsewhere.

Cognitive demands of stochastic events. Complexity is added to the task when it is interrupted by stochastic events. *Stochastic events* are randomly occurring and unpredictable events that are properties of new technologies (Weick, 1990) and flexible manufacturing systems (Norros, 1996). When new technologies are implemented in industrial work processes they frequently produce system disturbances to which operators must respond, even though they have not yet developed expertise in the use of these technologies (Norros, 1996). Today's technologies present problems due to their instability, reduced transparency, and tendency to breakdown. For example, many software-dependent systems are intentionally pushed through product development and quickly delivered to market. Product testing is short-circuited since implementation is often the means by which the technology itself is designed. Such development-delivery tradeoffs result in "buggy" software, incomplete information networks, and password-activated technologies that won't start. Dealing with the disruptions from unfinished technologies and prototypes increases the cognitive demands placed on technicians who must use them.

When a sudden, unpredictable event disrupts a task, it triggers emotional arousal (Weick, 1990). Once emotion is stimulated it increases as long as the interruption goes unexplained, especially when work stoppage is costly or risky. Stochastic events require rapid movement from emotion to action—from arousal, to the search for explanations, to actions that produce information about possible causes. This occurs as the worker tries to subdue emotional interference with thought and action.

Cognitive demands of systemic interdependence. The interdependencies needed to assure that one's work is coordinated the work of others have been termed *systemic interdependence* by Adler (1986). Systemic interdependence requires "ongoing and flexible integration of hitherto distinct functions of operations, systems, design, and training. The reciprocal nature of this interdependence in operations is exemplified in the reliance on common databases. Users thereby become dependent on other users' data input accuracy" (p. 19).

Systemic interdependence requires interpersonal skills and the ability to work effectively with others on the same project despite different social and technical backgrounds. Such interdependence is strengthened through the use of *transactive memory systems* (Wegner, Erber and Raymond, 1991). Transactive memory is based on the premise that we need not know a particular subject ourselves if we know where to find information about it. Transactive memory systems are integrated and differentiated structures in which related information is held by different group members. It is the sharing of relevant data that yields the higher-order insights and generalizations that are valued in these work environments.

These four task characteristics—*contingent versus deterministic tasks, distancing technologies, stochastic events,* and *systemic interdependence*—place unique cognitive demands on those who use them. How well do current theories of learning address these cognitive demands? The next section discusses the extent to which four selected theories explain human cognition and learning as they relate to the use of new technologies.

Theories of Learning and the Cognitive Demands of New Technologies

The theories of Scribner (Tobach et al, 1997), Schon (1983, 1987), Wenger (1998), and Hutchins (1995) are analyzed for their power to explain learning processes related to new technologies in the following sections.

Scribner's model of practical thinking at work. Scribner used *activity theory* as developed by Leont'ev (1981) to bridge the conceptual relationship between knowing and doing in her cognitive studies of work. Scribner's model of practical thinking is strongly influenced by the notion of activities as mediators of knowing and doing. The collection of Scribner's cognitive studies of work concludes with a paper that presents her model of practical thinking (Tobach et al, 1997). The model is organized around four principles synthesized from Scribner's studies of dairy workers (Scribner, 1984), industrial machinists (Martin and Scribner, 1991), bartenders (Scribner and Beach, 1993), indigenous literacy in West Africa (Scribner and Cole, 1981), and practical and theoretical arithmetic (Scribner and Fahrmeier, 1983). Scribner's research sought support for the premise that cognitive skills take shape in the course of participation in socially organized practices. Her results are embodied in the four principles of her model: (a) economy of effort functioned as a criterion distinguishing skilled from amateur performance. The "least-effort strategy" was consistently followed whether mental or physical effort was minimized and regardless of resource constraints in the work environment; (b) problem-solving strategies were dependent on specific knowledge about materials and conditions in the immediate task environment; (c) diversity and flexibility of solution modes distinguished expert problem-solvers from beginners; (d) more experienced workers replaced all-purpose algorithms with a menu of solution modes fitted to properties of specific problems in changing environments. Scribner summarized the four principles in this way: "Thinking in the dairy was goal-directed and regulated by a principle of economy which, operating under changing conditions and on the basis of knowledge and information in the environment, generated flexible solution procedures adapted to particular occasions of use" (Tobach, 1997, p. 380).

Scribner's work and the cognitive demands of new technologies. Scribner's work demonstrated that workers seek pragmatic solutions through economy of effort regardless of the contingent or deterministic structure of the task. Her study of working intelligence (Scribner, 1984) fully accounts for task unpredictability and the need to go beyond scripted procedures to accommodate the changing demands of the task environment. For example, since each dairy order was different, delivery drivers modified their problem framing and arithmetic solutions to conform to the benefits of either their calculators or paper and pencil computations. Ways of solving problems followed means of arriving at solutions.

Scribner's model emphasizes that successful work strategies are goal-directed and vary adaptively with the changing properties of the problems and resources encountered by workers in the task environment. It explains how workers might respond to stochastic events by relying on flexible solution strategies and improvising with available tools and materials. Task disruptions might trigger the reassessment of means-ends relationships and solutions would reflect Scribner's concept of mental and physical effort saving. Contextual factors would strongly influence how workers in a production environment learn and adapt their skills on-the-job.

Scribner's model was developed twenty years ago before technologies considered new today were developed. While today's workers may use Scribner's least-effort strategies and context-specific solutions, it is unclear how well Scribner's model of practical thinking would address the cognitive demands of new satellite or internet-based

distancing technologies or explain the roles of inference and mental modeling to enable more effectively use these technologies.

Schon's theory of reflection-in-action. Schon (1983) argued for a new epistemology of practice that takes as its point of departure the competence and artistry already embedded in skillful practice—especially, the *reflection-in-action* through which professionals think about what they are doing while they are doing it. Reflection-in-action is a theory of learning that explains how reflective practitioners use knowledge and problem solving in their work. *Reflection-in-action* is an iterative process that moves through (a) assessment of the situation, (b) testing of one's preliminary sense of the problem through experiments, (c) examination of results, and (d) reassessment leading to another cycle of problem reformulation. Learning occurs through an iterative process of purposeful actions, discovered consequences, implications, reassessments, and further actions. We conduct experiments to examine the validity of our judgments and, in the process, expose ourselves to new possibilities for learning. According to Schon (1983), "the situation talks back, the practitioner listens, and as he appreciates what he hears, he reframes the situation once again" (p. 131). This theory of learning prompted Schon to raise a critical question: What kind of professional education would be appropriate to an epistemology of practice based on reflection-in-action?

His subsequent work (Schon, 1987) answered this question by proposing that university-based professional schools should learn from such deviant traditions of education for practice as studios of art and design, conservatories of music and dance, athletic coaching, and apprenticeship in the crafts, all of which emphasize coaching and learning by doing. Professional education, Schon argued, should be redesigned to combine the teaching of applied science with coaching in the use of reflection-in-action strategies. He proposed a generalized educational setting, the *reflective practicum*, as a model for professional development in which learning occurs by doing, with the help of coaching, especially through a dialogue of reciprocal reflection-in-action between coach and student.

The reflective practicum is a methodology for implementing reflection-in-action in the sense that it brings together the necessary material and contextual resources, along with the coach's personal and technical support for critical reflection. It provides an environment in which students can learn by doing, not simply through trial and error, but through critical refection as students are coached in refection-in-action strategies.

Reflection-in-action begins with a situation that yields spontaneous routinized responses. As long as the situation appears normal, our responses are tacit and spontaneously delivered without conscious deliberation. Yet routine responses sometimes produce a surprise—an unexpected outcome, pleasant or unpleasant, that does not fit our present knowledge schema. This unexpected consequence triggers reflection. We think about the consequence and ponder why it occurred and, at the same time, we ask "How have I been thinking about this?" Our thoughts turn back on the surprising phenomenon and, at the same time, back on itself. Thus, reflection-in-action is a critical function through which we consciously or unconsciously question the assumptions of our present knowledge.

Schon's work and the cognitive demands of new technologies. Schon's theory accounts for contingent tasks by acknowledging that professionals are frequently confronted by novel situations and must construct their interpretations and responses accordingly. Schon recognized that procedural knowledge and problem solving algorithms have limited applications in practice, where most problems are contextual and difficult to predict. The capability for reflection-in-action addresses these cognitive demands by allowing workers to bypass scripted procedures to arrive at solutions for problems that cannot be fully anticipated in advance.

Reflection-in-action also explains the cognitive processes needed to respond effectively to stochastic events. A sudden disruption arouses emotion and triggers reassessment of means-ends relationships. Schon's discussion of mental experimentation explains how workers might respond to a sudden systems failure by probing the unexpected disruption, forming a tentative understanding of the event, testing their understanding, and reframing the problem to arrive at a solution. Thus, workers respond to emergent situations by constructing new knowledge through reflection-in-action.

Although Schon's theory can be used to explain how workers meet these cognitive demands, its applicability to non-professionals and in non-university settings is less apparent. Schon's theory reconceptualized teaching and learning in the professions. What about technicians, supervisors, and skilled personnel who may not be considered "professionals?" Are these people considered capable of learning through "reflection-in-action?" In addition, Schon's work provided a new model of education for university-based professional schools. What about the learning that occurs outside of schools as one develops on the job? Does Schon's model for educating the reflective practitioner apply to learning in the workplace that may occur after a university-based education? These questions remain unanswered.

Communities-of-Practice. Communities-of-practice are informal associations of workers who share common work problems and seek the benefits of learning from one another. In such communities, learning occurs primarily through participation in social practice (Wenger, 1998). Underlying communities-of-practice as an observable

phenomenon is Wenger's theory of social learning. The theory embodied in communities-of-practice builds on previous work in social learning theory and situated cognition. Social learning theory explains learning as a product of the reciprocal interactions among behavior, cognition, and environmental factors. Learning can occur directly, especially when one's learning self-efficacy is high, or vicariously through behavior modeling by others (Bandura, 1977). Situated cognition starts with engagement in the activity itself, not with a preconceived model of how learning should occur. Situated cognition follows an "activity—perception—representation" model, in which the cognitive dynamics of learning appear less open to the predetermined knowledge schemas that are dominant in formal instruction (Brown, Collins and Duguid, 1989). When people lack experience with a situation or are introduced to a new concept, presenting a relevant model may catalyze the formation of mental representations of what is learned. Along with new perceptions and relevant past experiences, the model becomes part of the present context for learning, in which the learner's activities and perceptions precede mental representation.

Four constructs comprise the framework for Wenger's theory of learning: *practice*—the shared historical and social resources, frameworks, and perspectives that can sustain mutual engagement in action; *community*—the social configurations in which our enterprises are defined as worth pursuing and our participation is recognizable as competence; *identity*—how learning changes who we are and creates personal histories of becoming in the context of our communities; and *meaning*—the ability to experience our life and world as meaningful. Wenger's assumptions about learning and the nature of knowledge include the premise that meaning—our ability to experience the world and our engagement with it as meaningful—is ultimately what learning is to produce. Another assumption that grounds communities-of-practice is that engagement in social practice is the fundamental process by which we learn and so become who we are. Thus, communities-of-practice provides a broad conceptual framework for thinking about learning as a process of social participation.

The concept of *practice* is carefully defined by Wenger as experiences that include both the explicit and the tacit. Practice involves the language, tools, documents, images, symbols, well-defined roles, specified criteria, codified procedures, regulations, and contracts that various practices make explicit for a variety of purposes. But is also includes the implicit relations, tacit conventions, subtle cues, untold rules of thumb, and so on. Most of these are never articulated, yet they are unmistakable signs of membership in communities of practice and are crucial to the success of their organizations. Learning in practice addresses the need for members to acquire skills and information, but learning goes beyond gaining competence. Members use competence to form an identify of participation. "Practice connotes doing, but not just doing in and of itself. It is doing in a historical and social context that gives structure and meaning to what we do. In this sense, practice is always social practice" (p. 47).

Identity in a community is fostered by allowing members to participate peripherally, yet legitimately in practice. Legitimacy and peripheral participation in practice are often mutually exclusive. Newcomers seeking to participate in the work of a community of practice are granted peripherality (for example, as students) but denied legitimacy. Conversely, newcomers may be granted legitimacy but are denied the opportunity for development through peripheral participation. The periphery of practice is not only an important site for learning, but it can be a valuable source of innovation. Sustaining the peripherality of members' perspectives is sought increasingly as a way to generate fresh insights into current practice and new directions for the future.

Wenger's work and the cognitive demands of new technologies. Participation in communities-of-practice allows each member to draw on collective knowledge to construct responses to unanticipated or poorly-structured problems. Wenger illustrates his theory with ethnographic accounts of insurance claims processors who had to respond to customers' questions about claims coverage given only standardized forms and procedures and without full knowledge of how contested claims were ultimately resolved. The tasks they faced were made more contingent by customers' concerns about co-payments and company concerns about overpayments, especially in cases of multiple coverage. Workers tried to make sense of these ambiguous situations primarily through social configurations—the networks that claims processors spontaneously formed with each other, not by following claims processing procedures. Communities-of-practice allowed workers to go beyond standardized procedures and reach pragmatic solutions through mutual engagement.

The creation of identity is at the core of how communities-of-practice enable members to meet the cognitive demands of new technologies. Wenger maintains that who we are and what we can do are transformed through the process of becoming members of communities-of-practice. Identity and membership permit further engagement in social practice and access to collective knowledge. Although a member may lack specific knowledge about a problem, communities-of-practice provide collective knowledge that enables a response to the unpredictability and ambiguity of new technology (Orr, 1996). Legitimate peripheral participation (Lave and Wenger, 1991) and identity (Wenger, 1998) allow members of communities-of-practice to share the insights and generalizations that help them meet the cognitive demands of new technologies (Weick and Roberts, 1993).

Although Wenger's theory addresses the cognitive demands of new technologies, other questions about the theory remain unanswered. The theory's main concepts—meaning, identity, community, and practice—are defined as vehicles through which individuals can find fulfillment through their membership in communities-of-practice. Each is defined in a personal way as a phenomenon that, if experienced as part of a community-of-practice, can change who we are and how we interpret the world around us. However, there is an intimacy about communities-of-practice that seems removed from the realities of work and the turmoil of the marketplace—the environment in which communities of practice must survive. In this way, the theory does not fully explain organizations as system in which the learning of members is directly influenced by the demands of forces and stakeholders external to the system.

Cultural cognition. Hutchins (1995) conceptualized cognition as a complex phenomenon in which practice, learning, and the work environment are all simultaneously transformed. "The very same processes that constitute the conduct of activity and that produce changes in the individual practitioners of navigation also produce changes in the social, material, and conceptual aspects of the setting " (p. 374). These changes occur at different rates and degrees of intensity and reflect histories of different lengths, but they all intersect during any moment in human practice. In the course of task performance, learning occurs and these activities create elements of representational structure (for example, written notes or an improvised tool) that survive beyond the end of the task. It is because these processes interact simultaneously that Hutchins considers cognition at work a fundamentally cultural process.

Hutchins argues that as sociocultural systems, work environments have cognitive properties that are distinct from the cognition of those who perform the work. He confronts contemporary thinking in cognitive science by challenging the adequacy of symbolic processing alone to explain how we use cognitive abilities to solve environmental problems: "Notice that when the symbols are in the environment of the human and the human is manipulating the symbols, the cognitive properties of the human are not the same as the properties of the system that is made up of the human in interaction with these symbols. The properties of the human in interaction with the system produce some kind of computation. But that does not mean that the computation is happening inside the person's head" (p. 361). This appreciation that knowledge can only be created through human interaction with the sociocultural system is the foundation for Hutchins' theory of cognition.

Hutchins' work and the cognitive demands of new technologies. Hutchins opens *Cognition in the Wild* (1995) by describing a stochastic event—the USS Palau loses all power and risks running aground in a narrow channel while entering San Diego harbor. Only through expert navigational skills and some luck is the crew able to recover the vessel and safely come to anchor.

To meet the cognitive demands of these situations, workers must quickly overcome emotional arousal and construct solutions from procedural knowledge, environmental short-cuts and bricolage (Levi-Strauss, 1966). Hutchins shows that this process is strongly shaped by the tools and techniques of practice, themselves historically-developed. Learning is made easier in work settings where tools are used in public and the details of technology are observable, as they are in the practice of navigation. Hutchins describes how the difficulty of piloting large ships is made easier by implementing the *fix cycle*—a series of procedures in which representations of the position of the ship in its environment are propagated across a series of representational media from initial telescope sightings to correcting of the ship's course. These tools transform the task of navigators by mapping it into a domain, using the navigation chart and other artifacts, where the answer or the path to the solution is apparent.

The fix cycle illustrates a central premise of Hutchins' theory of cultural cognition—the cognitive demands of complex tasks are best met by using technology to simplify the task, not to amplify cognitive ability. Illustrating the same point, Norman (1997) gives the example of using a computer for writing. Instead of designing computers and software programs to help the author create ideas with dialog boxes, menu choices, and other symbolic clutter, the computer should be used as a word processor to simplify the output process. Rather than extending one's cognitive abilities, technology should transform what are normally difficult cognitive tasks into easy ones.

Implications for Further Research

This study has several implications for future research. This section summarizes key ideas from the preceding discussion and offers directions for future research on theory building.

Some features of sound theories. The four theories of learning discussed in this paper provide comprehensive and meaningful explanations of learning at work. Why is this? Considering the need to reflect the workplace, what are the features of a good theory of learning? Five features of the learning theories covered in this paper are summarized next.

Each theory describes specific cognitive processes. Schon describes the dynamic of learning as iterative cycles of reflection-in-action. Hutchins explains learning as a sociocultural process that occurs simultaneously with the

activities of practice and changes in the environment. Scribner described the specific solution strategies that were devised by experienced workers. Wenger described how learning in practice is generated by the dynamic tension between experience and competence. All four theories describe specific cognitive processes and clearly explain how learning relates to other aspects of the theory.

Each theory addresses learning as an enabler and product of work practices. Rather than treating either learning or work practice as dominant, each theory reflects their reciprocal relationship by grounding learning in the conduct of practice. Work practice is one of four central concepts in Wenger's theory of social learning; Schon proposed the *reflective practicum* as the setting to operationalize his theory; Scribner showed how cognitive skills were dependent on the materials and conditions of practice; and Hutchins proposed practice as the intersection of work activity, learning and the environment, where all are simultaneously transformed.

Each theory explains how learning occurs in authentic work settings. Each theorist relied on ethnography or intimate knowledge of practice to describe the work settings and define the tasks in which learning was studied. None of the studies from which these theories were derived were purely theoretical or carried out in laboratories or other experimental settings.

Each theory is comprehensive in its treatment of the behavioral and environmental influences on learning. These theories include concepts that cover the full range of ways in which working knowledge is created and used. Each theory accounts for personal and experiential knowledge, knowledge derived from practice-specific tools, techniques, and conditions, knowledge from relationships with others, and knowledge associated with the larger system, organization, or environment.

Each theory offers propositions that can be generalized to other settings. Although each theory is based in studies of specific work environments and occupations, all theories offer principles of learning that have been applied elsewhere. Scribner's "least-effort strategy" has been demonstrated in non-industrial settings (Scribner and Cole, 1981; Scribner and Fahrmeier, 1983). Schon's reflection-in-action has been applied to the preparation of architects, urban planners, artists, musicians, and althletes (Schon, 1987). Wenger's theory has been used to explain communities-of-practice among photocopier repair technicians (Orr, 1996), refrigeration technicians (Henning, 1998), and insurance claims processors (Wenger, 1998). Hutchins' work has been applied to airline pilots (Hutchins and Klausen, 1996) and to the design of the human-computer interface (Hutchins, Hollan and Norman, 1986).

These five features of the learning theories discussed in this paper provide a template for developing better theories of learning. In addition to the criteria for evaluating theory offered by Bacharach (1989), Patterson (1983), and Whetten (1989) that can be applied to all theories, the features listed above are specifically applicable to theories intended to model the dynamics of learning and working.

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A Study of Technology Transfer for Thai Workers in Thailand

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The paper will show how to make an effort toward the transfer of technology as major issue in Thai manufactures. The paper intends to provide someinsights into the transfer of technology from skilled foreign workers to Thai workers in Thailand. The managers, government, and educators have played an essential support role in the transfer of technology and haveencouraged Thai workers to absorb and adapt the new technology

Keywords: Transfer of Technology, Skilled Labor, Training

Since industries in Thailand are growing, there is an increasing need for the transfer of technology from overseas. Thailand wants to approach industrialization with an open-economy and to promote exports. In order to do this; many researchers have recognized the importance of obtaining the appropriate technology. Chantramonklasi (1994) stated that the transfer of technology could assist the country in achieving its economic goals and could also improve the standard of living of Thai people. The government has also strongly promoted foreign investment in the industry. For instance, the government has provided some training programs, has promoted industries, reduced taxes, established government units such as the Board of Investment (BOI) to look after foreign investment, and has promoted exports. In addition, the government has encouraged some high technology small businesses, which need the most modern technology in order to manufacture goods or provide service. This means that the investment policy of the government is increasingly concerned with the entry of domestic firms into the industrial market. The country needs to invest in innovative Thai industries, which must compete worldwide, and also to encourage more technology transfer.

Such an investment policy is needed in order to convince foreigners to invest in Thailand. Some concern has been voiced regarding the investment policy of the Thai government, which allows foreign labor to work here. Firstly, there are more and more foreign workers coming into the country and this means Thai workers have less opportunity to get a job. The second concern is that the transfer of technology has not been accrued including the limited transfer of technology for local staff. Yet another concern is the scarcity of skilled local labor and the restrictions found in technology transfer agreements imposed by technology suppliers.

Unfortunately, few studies have looked specifically at how technology has been transferred to Thai skilled-workers. Some studies reported that Thai people were poorly trained. The manufacturer may be aware of the technology requirements for established products but it is still difficult to obtain or develop new product design. In addition, some studies have shown that even where information on technology is available, lack of relevant skills and low levels of education make the use of new technology difficult.

In addition, some universities were not sufficiently equipped to supply skilled manpower to the labor market. Even though many research activities by Thai universities were encouraged, they still are not successful. This is partly because of the poor co-operation between public and private sectors and partly because of a lack of explicit policy and effective measures on the government sector. Tambunlerchai (1980) had showed his survey that Thai partners of Thai-Japanese joint venture investment did not receive much of the technical know-how even they wanted to do so. The technology transfer has been neither sufficient nor effective since the shortage of basic training for the manufactures. Thai labors' effort has not been as productive as they should be since the education has not been geared to the real need of manufactures. There is less commitment from Thai labor. Furthermore, teachers have fewer experiences to transfer the knowledge to students. Students in universities are taught theoretically more than the actual practice. The curriculum doesn't modern. There is less workplace for training/practical training.

Therefore, this research focuses on the effectiveness of technology transfer in the manufacturing sector. The researchers will apply a quantitative and documentation approach including interviews, observations, and surveys. Moreover, data collected for the project will be analyzed to provide a broader picture in terms of the effectiveness of technology transfer and how to develop Thai workers.

Literature Review

Thailand's economic growth since the late 1980s has increased. This makes technology a more important element for national development. The current industrial policies of Thailand are designed to promote manufactured exports, labor-intensive industries and agriculture-based industries. The BOI is responsible for

these activities. The organization is empowered to offer incentives, guarantees, and measures to protect industries against competition, and special exemptions from various laws. Then, many manufacturers have imported technology from abroad in order to assist them in production and management. For instance, there are many manufacturers in Thailand which are Thai-Japanese joint-ventures such as Toyota (Thailand) Co. Ltd., Nissan (Thailand) Co. LTD, and Isuzu Motor Co. (Thailand) Ltd. Large and medium enterprises in the machinery industry have also formed joint-ventures, Thai investors holding about 50 percent of the total investment or less. In the electronic and electrical appliances industry, there are now about twenty large companies producing television sets, radio, refrigerators, integrated circuits, and parts of computers; companies such as Korat Denki Company, Minebear Company, Magnecomp Group Corporation. Many machines and equipment have been imported from abroad (Cooper, 1994) showing that industrial development has relied heavily on imported technology.

In Thailand, modern science and technology have involved the promotion of direct foreign investment and the encouragement of applied research activities by local universities. Foreign direct investment is seen by policy-makers as a way by which technology can be brought into the country, while the local research institutes and universities provide skilled human resources to absorb the new information. The general perception, however, is that the strategy of building capacities in local institutions has not met with much success, in part because of the absence of effective linkages between the public and private sectors, as well as the lack of explicit measures and schemes to promote technological literacy.

This situation has created some concern about technology transfer including
Limited transfer of technology to local staff, restrictions found in technology transfer agreements which were imposed by technology suppliers, the stated and hidden costs of technology agreements, the inappropriateness of the technology introduced, and the scarcity of skilled local labor. For instance, the Thai-Japan joint ventures have failed to transfer the know-how technology to Thai local partners. (Chantramonklasri, 1994)

Another concern is that the report traces the vicious cycle within which many local companies are caught. It begins with a market for technology in which a small number of suppliers face a large number of buyers, with whom costs, terms and conditions are determined individually on the basis of crude bargaining power rather than competition (Chantramonklasri, 1994). Moreover, the buyers are usually uninformed and lack the technical and legal expertise to evaluate alternative sources of technology and to negotiate effectively with suppliers. As a result, contracts are concluded to the advantage of the supplier and the buyers accept restrictions, which have the effect of increasing their dependence on the technology suppliers.

Although the transfer of technology is usually identified with the inflow of foreign capital, there have been questions raised about the prices paid for technology. The disadvantaged position of the buyer and his ignorance about the costs of alternative sources has resulted in unreasonably high profits for the owners of technology (Cooper, 1994). The government study reports that the evaluation of an offer to supply technology grows in complexity when the technology is offered in packaged form, with technical assistance and management provided (Khanthachai, 1987). The offer may contain many hidden costs. In addition, some reports provide information to support the contention that the outflows of funds (foreign remittances and expenses for import receipts) have exceeded fund inflows (foreign capital infusions and export receipts) among Thai joint ventures that have been paying copyright fees and royalties (Ng, 1986).

The technologies that foreign firms have introduced are generally inappropriate or excessively capital-intensive, given the labor surplus conditions in these countries as mentioned earlier. Moreover, these technologies are seldom adapted to make better use of local factor endowments. Some foreign companies have introduced second-hand equipment and pass it off as "labor-intensive, appropriate technology" (Chantramonklasri, 1994, p.49). These are usually machines that have become less efficient and have to be replaced in the supplier's country. The unfortunate impact on the host country or on the technology buyer is usually high maintenance costs, which offset the benefits gained from increased employment, and cheaper equipment costs.

The shortage of skilled labor is regarded as another major problem to the effective transfer and absorption of technology. The various skills training programs are unable to cope with the needs of the extremely large labor pool and the requirements of industrial firms (McLeod, 1988). Moreover, the educational system has thus far failed to keep up with the demands for more science-based, technically grounded, and relevant educational programs. The potential for technological absorption and control is related to the availability of qualified and experienced technical personnel. Although such individuals are to be found in most Thai research institutions, the report showed that such institutions have been unable to adequately supply the requirements of private industry (Khantthachai, 1987).

The limited utilization of R&D capability is isolated and disconnected in the real world. The researchers carry out technology activity in an improper manner. Even though there is an attempt to commence R&D programs, they are often unable to have an impact on the industry. A well-known argument often used to explain this ineffectiveness is that industrial firms have a tendency to utilize proven technologies from foreign sources, thus limiting the demand for local scientific and technological capabilities (Ng, 1986). This argument

remains highly questionable because it presumes that those "centers of excellence" have available the kinds of products which are relevant to the needs of their potential clients. As noted by an empirical study, "industrial firms tend to doubt the ability and effectiveness of universities and public technical institutes to solve practical industrial problems" (TDRI, 1992a, p. 85).

According to some statistics in the country report, advanced countries have a higher level of national investment in R&D. For example, Japan spent about 3 percent of its GNP and newly-industrialized countries like Korea, Taiwan and Singapore spent about 1 to 2 percent of their GNP in R&D (TDRI, 1992). The R&D investment in Thailand in recent years was less than 0.2 percent of GNP. It shows that Thailand is less interested in R&D investment which, in turn, causes the country to develop slowly.

Another problem is that many firms can draw sources of technology from foreign sources and that lead the firms to feel that there is no need to invest in R&D. Since the firms receive efficient technology, they then assume that everything will be fine. They tend to remain passive until the new production system has arrived and engage in limited technological training. They remain unaware of industrial firm's need to develop in-house technology.

For the reasons mentioned above, Thailand is not ready for the transfer of technology and therefore remains less competitive. Moreover, there are many new market economies with lower wages and more resources. There are also many developed countries, which have researched new production techniques and are able to make new products. This makes Thailand even less competitive and could become a serious problem in the future. It is thus highly possible that without substantial efforts to develop better capability in science and technology and to support industrial development, Thailand may face a major economic and social crisis in the near future.

Furthermore, transfer capabilities and motivation of the enterprises supplying industrial technology have an important bearing upon the effectiveness and efficiency of technology transfers. The competence of the transfer agents, including their ability to design an easily transferable technology package, is an important factor. The supplier enterprise and its transfer package report a combination of documentation, training and technical assistance. Motivation of the technology supplier depends in large part on the transfer mode and the potential return the supplier hopes to realize by an effective and efficient transplant.

Conceptual Framework

The transfer of technology between developing and developed countries has been happening for long time. It has caused the technology gap to get wider and wider. There are a few countries in Asia, which have crossed the gap and developed a national technology of their own. The essential question is why. Why has so little worthwhile know-how flowed to developing countries? The researchers believe that there is no one answer to the question. There are some studies focusing on the success and failure of some factories. Some failures in the transfer of technology result from poor negotiating technique and poor contract drafting, poor English language, and poor skilled-labor. Some successes occur because the negotiators knew what they wanted, knew how to bargain for it, and knew how to draft the necessary contract.

This paper studies the effectiveness of transfer technology for Thai workers. The technology transfer may be described as the "diffusion of the complex bundle of knowledge which surrounds a level and type of technology" (Charles and Howells, 1992, p.3). In this case, the technology transfer refers to the movement or passing-on of technology or know-how from one party to another via the use of investment or agreements for cooperation between two or more parties in the manufacturing industry in Thailand.

This study uses the above definition and views that technology can be transferred and various distinct mechanisms for effecting the transfer. This paper will be beneficial to international human resource managers, policy-makers, Thai workers, and educators. After they read the paper, they will find that the research studies focused on the effectiveness of technology transfer for Thai workers. They will learn that the technology transfer is a main key for Thai development and sustainability. It will assist Thai manufactures to know their problems and learn about technology transfer. They will know the trend to produce Thai workers to replace the workers from abroad and determine the criteria for bring in foreign workers.

The questionnaires were divided into four groups. They were human resource managers/entrepreneurs, Thai workers, foreign workers, and institution administrators. The questions were divided into two sections in each group. They were general questions such as position, responsibility, gender, and so on. The second section was about how the technology had been transferred, what type of training were employed, how long they worked in the manufacture, who trained Thai workers. Some of the questions for investigation are:

- In using which technologies are Thai workers' skills are not as good as they should be?
- Does the manufacturer provide training to Thai workers?
- How does the manufacturer develop Thai workers after they have transferred the technology?
- What are the advantages and disadvantages of hiring foreign workers?
- How can the government assist with the transfer of technology?

This, in turn, will assist Thai manufacturers to know their problems, and to learn about the transfer of technology

Research Methodology

Methodology

This paper is based on a multi-method component and design research methodology. Under this design, the combination of components occurs since the earlier stage launched the literature review, data collection, data interpretation, and analysis. Many books, journals, and other documents on the transfer of technology were reviewed. The sources were Thai human resource and technology journals, organizational development journals, and the Internet.

The questionnaires were discussed by the team researchers many times in order to clearly define and make sure that all details were covered. The questionnaires were pre-tested and modified.

In this study, we utilized stratification in order to have a variety of sampling in four groups. Further, we showed the questionnaires to committee members at the BOI for comments and suggestions. The advisory committee for the study determined that the most knowledgeable and most likely to provide insights into the subject under investigation would be: Foreign workers (150 persons), Thai workers (100 persons), senior administrators in schools (50 persons), and entrepreneurs or human resource managers (50 persons). The people were drawn from five provinces: Rayong province, Ayuttaya province, Chonburi province, Lumpun province, and Songkla province. The manufacturers were selected from a list of participants who were willing to participate in the research.

While the questionnaires were being distributed, key workers were interviewed because they were the most knowledgeable about the topics being researched, could provide a current perspective, and were able and willing to communicate withthe research team members.

Research Question/Proposition

What is the effectiveness of technology transfer for Thai workers?

Research Limitation

The research is to study a technique the effectiveness of technology transfer for Thai workers.

Words of Definition

Transfer of technology is defined as a knowledge transfer from supplier (usually a developed country) to the receiver (a developing country).

Foreign workers are defined as foreigners who are granted a work permit by the BOI to work in Thailand.

Thai workers are defined as Thai workers who work in the manufacturing sector

Human resource managers are defined as the manager who is responsible for personnel management.

Institution is defined as Thai higher education institution.

Entrepreneur is defined as one who organizes a business.

Results and Findings

The questionnaires were distributed to four groups. They were 50 HR managers/entrepreneurs, 100 Thai workers, 150 foreign workers and 50 institution administrators. The research took about one and a half months in the field. The study included twenty-four manufacturers from four regions of Thailand and ten institutions. This section will discuss some important issues on the effectiveness of technology transfer for Thai workers.

The first set of questionnaires was distributed to HR managers/entrepreneurs. Every factory had hired a foreign worker with a work permit. Most of them came from Japan, China, Taiwan, Korea, Philippines, Malaysia, Singapore, Pakistan, and India. A few of them came from the United States, Canada, Britain, France, Italy, and Australia. These people hold positions of senior and middle managers and technicians. Examples of positions are mechanical manager, marketing manager, managing director, quality audit manager, shift supervisor, maintenance supervisor, R&D manager, production manager, tooling design specialist, process development manager, and information system manager. Many managers stated that some of these workers have transferred technology and increased the experience and knowledge of Thai workers. They also mentioned that there is an organizational policy to reinforce the transfer of technology in more than 76% of the companies.

The reasons are that Thai workers are cheaper and are able to do the job. The four types of transfer of technology are shown in Table 1 and the method of transfer of technology in Table 2 as shown below.

Table 1. *Type of Transfer of Technology*

Type of the Transfer of Technology	Percent
Mechanism	80.9%
Production	70.2%
Management	51.1%
Marketing	31.9%

Table 2. *Method of Transfer of Technology*

Method of Transfer of Technology	Percent
On the job training	89.4%
In-house training	76.6%
Training abroad	61.7%
Training in Thailand	51.1%

After transfer of technology has occurred, 76.6% of the respondents are willing to replace foreign workers in middle management positions such as plant manager, control manager, mechanical technician, safety and environment manager, and production technician. The factory also has a plan to continuously develop Thai labors in order to keep up with the new technology. They will provide coaching, in-house training, and simulations, and will also require self-evaluations and portfolios.

In addition, the respondents also provided what they believe to be the advantages and disadvantages of hiring foreign workers. The advantages include: technology transfer to Thais, exchange of culture, improving communication with their mother company, providing new technology and knowledge, experience and specialist knowledge, and receiving suggestions and recommendations. The disadvantages include: high cost, cultural conflict, language barrier, little transfer of technology, difficulty in obtaining Thai visa, and conceited opinions about Thai people.

On the government side, responses indicated a need for some assistance from the Thai government are to encourage Thai people to learn foreign languages, train Thai people to understand foreign cultures, improve the school curriculum including teaching and learning, send students for training, reinforce the law requiring foreign labor to help Thai society, coordinate between the government and industry, provide training packages, establish a center providing advice about experts in technology within Thailand and abroad.

The second set of questionnaires was distributed to foreign workers. The responses from the survey showed that the average age of the foreign workers is 41 years old, the average years of experience is 14 years and the average salary is 80,080 baht ($1,777 per month). The respondents were 98% male and 2% female. Their education details appear in Table 3

Table 3. *Level of Education of Foreign Workers in Thailand*

Level of Education	Percent
Less than secondary school	15%
Vocational school	32.2%
Bachelor Degree	44.9%
Higher than Bachelor Degree	7.2%

The foreign workers were 79.9% Asian, 11.4% European and 6.7% American. Most Asians came From Japan. Others came from Taiwan, China, Korea, Malaysia, Singapore, and India. Their positions are president, vice president, manager, assistance manager, and technician. Their main jobs include quality control, quality audit, organizational management, safety, production design, contacting customers, supervise workers, product marketing, investment planning, coordination, and maintenance. These people came to Thailand because their mother companies sent them to help Thai team members improve their skill and learning. This has created an opportunity for training and transfer of technology to Thai workers. However, there are some difficulties. For example, the language barrier, ineffective communication, and cultural conflict. Others problems include Thai staff quitting their job after training in order to get a better job, Thai workers not paying attention to what has been taught, and foreign and Thai workers sometimes misunderstanding each other.

The third set of questionnaires was distributed to Thai workers. The survey showed that the Average age of Thai workers is 31 years old, the average years of experience are 5, and the average salary is 20,262 baht ($406 per month). The responses were 83% male and 17% female. Their education details are shown in Table 4.

Table 4. *Level of Education of Thai Workers*

Level of Education	Percent
Less than secondary school	17.9%
Vocational school	21.1%
Bachelor degree	50.0%
Master degree	6.3%

The respondents hold positions as middle managers, for instance, head of technicians, and Directors of production According to the respondents, Thai people for several reasons can hold these positions. Thai people have more experience, work hard, are responsible, and are willing to do the job, like a challenging job, and always develop themselves. In addition, many respondents stated that Thai workers have the same opportunity to progress in their job as foreign workers do. They work and coordinate with foreign staff and learn techniques from them. The Thai respondents all stated that they attended a variety of training courses such as for industrial orientation, professional management, internal auditing, foreign languages, manufacturing, ISO 9000, ISO 14000, safety and energy -saving, and time management. The technique for effective transfer of technology is to work closely with foreign workers, practice by yourself, do tests, coordinate projects, train on the job, and do training abroad or in professional conferences.

The fourth set of questionnaires was distributed to the institutional administrators. Almost all (95%) of the respondents are from public institutions. Their courses are in the fields of engineering, food technology, industrial technology, ceramics, computers, economics, food science, accounting, marketing, hotels and tourism.

The institution's policy is to produce graduates who can think, work, be responsible, and Communicate, including using a foreign language. A question related to whether the institutions knew about the need for the number of Thai workers in the manufacturing sector. Many of them didn't know (52%). The question asked further about how they knew about the needs of factories. The result shows that the institutions knew about the need from provincial labor council's (5.45), announcements by the factories (13.5%), and from the BOI (5.4%). There was no answer from 75.7%.

In order to help manufacturers find qualified workers; all institutions have a counseling unit where they work closely with students and manufactures. The name of the unit differs: counseling department, counseling unit, career and development section, careers information section. Their jobs are to provide counseling, help students find jobs, coordinate with the Ministry of Education, and provide career information.

The respondents also state that students in the institutions have an opportunity to learn and practice their skills in a factory in order to increase their experience, and sometimes attend training courses which last from 2 months up to 2-3 years. The techniques to train students in Thailand are summarized in Table 5.

Table 5. *Techniques to Train Students in the Institutions*

Techniques to Train Students	Percent
On the job training	76%
Learn from foreign workers	49%
Invite foreign workers to teach in school	35%
Learning through documentation	15%

Some problems for Thai institutions producing graduates are: unclear national policies for higher education, a lack of personnel and equipment, inexperienced teachers, insufficient budget, lack of private coordination, lack of language and culture skills, outdated curriculum, insufficient activities for students to participate in the field.

The final question was to ask whether the government can help to improve the Transfer of technology to Thai workers. The responses were to determine how to transfer the technology, encourage more development of technology, provide training and more education, provide scholarships for further education, coaching and mentoring lectures and participation, a clearer policy on the transfer of technology, improve quality of education. Furthermore, the responses mentioned that there should be coordination with foreign investors, a focus on specialists, support for the exchange of technology among the industries, a transfer of technology center, enough budget, a new curriculum with an emphasis on foreign languages, more foreign investors in Thailand, more seminars, workshops, conferences, and other activities that involve the transfer of technology.

Conclusion and Recommendation

In this paper, we analyzed the effectiveness of technology transfer. The findings show that the majority of foreign and Thai workers are male. Foreign workers hold positions of senior managers in the manufacturing

sector while Thai workers are junior managers. Foreign workers have an average experience of about 14 years while Thai workers have an average experience of about 5 years. This might be because the average age of foreign workers is much higher, 41 years, while the average age of Thai workers is only 31 years. The research displays that should distribute their new and advanced knowledge for Thai workers who have less experience. The technique mostly used by foreign workers for knowledge transfer is on-the-job-training.

The methods used for transferring technology include on the job training, in-house training, training abroad, and training in Thailand. This relates to engineering, production, management, and marketing. It shows that there are four main methods for the transfer of technology that most manufacturers in Thailand have implemented and found to work well. Manufacturers still feel that it is necessary to hire foreign workers because they would like to hire their own people to do their job. They feel that their people can do a better job and can be trusted more. In addition, there is the recognition that the Thai government and manufacturers play a major role in facilitating and supporting the process of technology transfer. The government is encouraged to support the process through the provision of required incentives, educational infrastructure and support institutions. It must be a strong collaboration between the manufacturers and the government for the transfer of technology to be successful.

Educational institutions offer courses that are out of date and not geared to keep up with the changes in technology. The responses from the manufacturers state that graduates can't do the work. However, the institutions have tried to help by providing practicum and have students do the actual work while in school. The equipment in schools for students to practice with is old. There is also a lack of qualified teachers. There is also a high turnover among skilled workers resulting in incomplete technology transfer to the local manufacturers. Consequently, the ability of Thai workers to absorb and adapt technology is weak.

New Knowledge to HRD

This research can contribute to the new knowledge in HRD by showing there is a growing awareness by manufacturers of the skills available to increase productivity and growth in industrial production. It shows the importance of educational and training opportunities to Thai workers so that they can improve their skills and compete in the world market. Education and training play an essential role in developing workers' skills. In addition, the government must be a strong supporter for the process of technology transfer.

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Impact of Technological Change on Human Resource Development Practices: A Study of Singapore-Based Companies

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Technological change is commonplace in contemporary organizations. How to prepare employees for technological change has increasingly become an issue for human resource development theory and practice. This study investigated the human resource development practices of organizations in Singapore, a nation that has been subject to many changes in order to stay competitive. The results show similar patterns of responses across business sectors, however some differences were found in the transport and communications sectors. On-the-job training was reported as the most frequently used training method to address organizational change needs. The discussion and recommendations focus on the need for improved change management approaches.

Keywords: Technology, Organizational Change, Singapore

Technology can be classified into three types: 1) product, 2) process, and management (Osman-Gani, 1996). Briefly, product technologies are when ideas are incorporated into a concrete object. Process technologies are the sequential steps used to produce a product or deliver a service. Management technologies are the actions taken to optimize resources to achieve business goals (Osman-Gani, 1991). Regardless of the type of technology, its appearance in organizations has definitively changed the nature of work (Connor et. al., 1996). Indeed, the greatest impact of technology has been suggested to be on the nature of work and the abilities of employees to meet the new requirements.

Responding to technological change ultimately places pressure on the costs of the organizations (Nankervis, Compton, & McCarthy, 1999). However, no research has been found to determine to what extent the effect that technology has had on human resource development practices, particularly in the Asian region. For instance, Singapore, being resource-scarce, naturally needs to invest in its people on a continuing basis. The following research questions were formulated to guide the study:

1. What are the major technological changes experienced by Singapore companies during the last three years?
2. What is the impact of technological changes on Training and Development practices of Singapore companies?
3. What is the nature of the resistance to technological changes experienced by Singapore companies?
4. What is the nature of differences among companies from various industrial sectors in using the T&D strategies to cope with the technological changes?

Methodology

The sampling frame of this study was from the 1999 "Singapore 1000" database. It was used because technological changes are more likely to impact dynamic organizations. A sample of 908 companies was selected randomly for each stratum, according to their representation in the sampling frame. The sample was selected using a proportionate stratified random sampling method with the strata being the five primary business sectors namely, manufacturing, construction, financial and business, transport and communication and commerce. Respondents were either HR managers or general managers. Preliminary interviews were conducted on a sample of 30 HR managers drawn from various companies. Interview findings were incorporated into the questionnaire design, which encompassed specific technological changes and the possible impact faced by companies on the various HR issues. Research findings from existing literature were also integrated. The questions were carefully worded to avoid misinterpretation. Technical terms were also explained.

The questionnaire layout was formatted in a logical and aesthetically pleasing manner to ensure higher response

rate. The structured questionnaire was designed using five-point Likert-type response scale and some categorical items provided for choosing frequency of use. A cover letter was attached to the questionnaire describing the purpose of the study with anonymity and confidentiality emphasized to increase the response rate. No identification such as company name or email address was requested from respondents. In order to verify the reliability and validity of the questionnaire, test and retest methods were used. The questionnaire was administered twice to a sample group within two months to check for accuracy and consistency. A panel of experts comprising of senior managers of companies and professors of Nanyang Business School, were consulted to check for adequacy and relevancy of the questionnaire items. The questionnaires were mailed to the HR managers and general managers of the sample organizations. Managers were requested to complete and return the questionnaires within two weeks either by mail or fax. Due to the initial low response rate, a second mailing was carried out, and follow-up calls were made.

Results

A total of 147 responses could be used for the analysis after screening the returned questionnaires for their completeness. The responses had the following demographic breakdowns: 51 percent of the respondents were from local companies and 49 percent were from foreign companies; 52 percent were from the SMEs and 48 percent were from large companies; 46 percent of the respondents were from the Financial and Business Services sectors, 21 percent were from the Manufacturing sector, 14 percent were from the Commerce sector, seven percent were from the Transport and Communication sectors, six percent were from the Construction sector and seven percent were from the remaining sectors. Finally, 70 percent of the respondents had business experience of more than ten years.

What are the major changes experienced by Singapore companies during the last three years? The results showed that in terms of information technology, in 1997 the introduction of new hardware affected approximately one-third of the companies. In 1998 and 1999, approximately one-half of the companies reported introducing new software. In terms of product technology, in 1997, 1998, and 1999, approximately one third of the companies introduced electronic telecommunications equipment. In terms of process and management technology, total quality management and accounting tools were the most frequently introduced areas of technology for all three years.

What is the impact of technological changes on human resource development practices of Singapore companies? The results showed that on-the-job training was the highest ranked training method used by Singapore companies to cope with technological change. The results also showed that most companies during this time used external consultants and vendors to provide human resource development expertise. The average length of time for the training was from one to three days in length. Surveys and questionnaires were the most frequently used training evaluation method used.

What is the nature of the resistance to technological changes experienced by Singapore companies? The results showed that psychological and emotional attitudes were the most frequent type of resistance encountered as a result of introducing new technology. The human resource development strategies used to reduce resistance to change. Communication and education, employee participation and involvement, and facilitation and support were the most frequently used human resource development strategies used.

What is the nature of differences among companies from various industrial sectors in using the HRD strategies to cope with the technological changes? Table 1 shows that overseas training was the most frequently used training method ($p.< .01$) and that the difference was found among companies in the transport and communications sector. Table 2 shows that there were no differences across the business sectors in terms of the nature of training providers used by companies. Table 3 shows that there were no differences in the training duration across business sectors. Table 4 shows that trainer feedback was significant in terms of the training methods used by companies in different business sectors. Again, the difference was found in the transport and communications business sector.

Discussion and Conclusions

Changes in information technology were most frequently experienced technological change in Singapore organizations. Recruitment and selection did not play an important role in helping a company cope with technological changes. Singapore companies were using other means such as training and development to cope with technological change. Employee training helped companies cope with technological change. However, tight training budgets constrained the type and frequency of training programs. Employees can be motivated to accept changes through the use of annual increment, medical benefits and training opportunities. Motivational strategies enabled employees to face technological changes more positively. The role of planning change lied mainly in the top management.

Companies can consider using contract workers on a temporary basis of six months to relieve current workload. This is because workers need not be trained since they can take over simple tasks and are relatively more cost-effective. This allows employees to focus on critical job aspects that are technology dependent while leaving non-critical work to contract workers. With the increasing usage of the Internet by Singaporeans, the applicant pool will increase and thus companies should consider the use of e-recruitment. This can be achieved by setting up a company website or by using e-recruitment services such as RecruitAsia.

Training can be used as an effective tool for motivating and retaining the employees. For example, scheduling an employee to a one-year overseas-training program can help to boost morale. The use of stock options can be useful in companies that faced many technological changes, which demands the full attention and energy of employees to innovate in order to survive. This increases the employee's commitment to the company and motivates him to work harder for mutual benefits. Non-monetary, innovative and valuable incentives could be used more frequently to enhance employee motivation. For example, a point-scheme based on work performance can be devised to replace overtime pay. Points accumulated can be redeemed for incentives such as free staff lunch and reduced working hours.

It is recommended that companies increase their training budgets to accommodate more training programs for employees. Training should be taken as an investment and not an expense. Training programs are needed to upgrade employee skills. Thus, there is a vital need for more resources to be allocated to training. Training programs should be structured to include technical training as well as management training. Of equal importance is the need for good change management and communication skills to ensure successful changes. Companies should continue using on-the-job training as emphasized by the Singapore government in their recent OJT21 initiative and seminars/workshops. Computer-based training should also be considered to enable employees familiarize themselves with computer-related and Internet applications. However, the use of specific training methods would depend on individual company's needs.

Outsourcing of non-proprietary training could be a good strategy as the management can focus on more important issues and redirect the training programs to people who have the expertise and knowledge about the change. This is especially so with the increase in information technology. Shorter training duration allows company to adapt to new technological changes and this enables companies to gain an edge over their competitors. Thus, duration of training sessions should be appropriate to allow employees sufficient time to absorb new knowledge. Companies should conduct some form of training evaluation. This is because it would prove to be valuable to the HR personnel in shaping and improving the company's future training programs.

Recommendations

As this study sampled only 908 companies, future researchers could use a larger sample of companies to improve on representation. The study only covered technological change and its impact on HR strategies, hence, researchers may want to consider studying other types of changes, such as organizational changes. Reasons driving technological changes and the frequency of changes can be investigated to determine an appropriate period for companies to retrain workers to cope with new changes. Techniques such as cascade training might be used to address institutionalization issues (Jacobs & Russ-Efty, 2001). Other HR issues such as career development, performance appraisal and industrial relations can be explored into. Organization variables affected by technological changes such as organization structure, job design, authority, responsibility and communication patterns could also be included.

To obtain a more comprehensive and in-depth study, employees could also be included as respondents to show the impact of various HR strategies on different interest groups. The length of business experience can also be incorporated to see if there are significant differences among companies of different years of experience in their use of human resource strategies to cope with technological change. Analysis between government-linked and private companies, as well as between listed and non-listed companies can be conducted. A comparison between technology firms such as Internet and software companies and non-technology firms could be examined for differences in HR strategies with regards to technological changes.

Future research should focus on more detailed interviews and focus groups to obtain more comprehensive views of the current situation. Specific case studies could be conducted on representative companies to gain an in-depth knowledge of technological changes' impact on HR within each company. The study may be replicated in other countries with an additional variable, national culture considered. It would be a valuable finding to prove that national culture varies from country to country hence enabling an Asian model depicting the impact of technological changes on HR strategies to be developed.

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Table 1. *Analysis of Variance on the use of Training Methods by Business Sector*

Frequency of use of Training Methods	Business Sectors																		F- Value	Signi-ficance
	Manufacturing			Construction			Financial and Business Services			Transport & Communication			Commerce			Others #				
	N	Mean*	SD	N	Mean*	SD	N	Mean*	SD	N	Mean*	SD	N	Mean*	SD	N	Mean*	SD		
Classroom/ Lectures	21	3.67	1.02	6	2.83	1.17	43	3.42	1.42	8	4.25	0.71	13	3.00	1.35	7	3.29	1.70	1.34	0.26
Seminars / workshops	18	3.89	1.08	6	3.50	0.84	44	3.89	1.13	8	4.00	0.53	14	3.71	0.83	7	4.29	0.76	0.50	0.78
Games and simulation	16	2.13	1.09	6	2.33	1.51	38	1.97	1.15	8	2.63	1.19	13	1.38	0.65	6	2.83	1.33	2.05	0.08
Small group discussions	18	2.89	1.02	6	2.50	1.38	41	2.95	1.20	8	3.00	1.20	13	2.92	1.12	7	3.29	1.50	0.29	0.92
Written tutorials	16	1.75	0.68	6	1.67	1.03	39	1.79	0.92	8	1.75	0.46	12	1.67	0.89	6	1.83	1.33	0.06	1.00
Audio and video tapes	18	2.61	1.04	6	2.50	1.38	38	2.26	1.35	8	3.25	1.28	13	2.15	1.28	7	3.29	1.70	1.49	0.20
Computer-based training	18	3.00	1.24	6	4.00	0.63	40	2.90	1.19	8	3.13	1.36	13	2.31	1.18	6	3.17	1.17	1.79	0.12
On-the-job training	20	3.95	0.94	6	4.17	0.98	43	4.14	1.08	8	4.38	0.52	13	4.38	0.77	8	4.00	0.76	0.46	0.80
Self-instructional materials	17	2.53	1.23	6	2.17	1.60	42	3.02	1.26	8	2.75	1.28	14	3.36	1.22	6	3.33	1.86	1.20	0.31
Overseas training	19	2.89	0.94	6	2.50	1.38	37	2.16	1.38	8	3.63	0.52	13	1.92	1.19	6	3.50	1.64	3.61✦	0.01

* *1 = Least Frequently Used .... ..5 = Most Frequently Used*

\# Includes companies from the healthcare, theatre and performing arts, IT and printing services.

✦ *significant at ≤ 0.05*

Table 2. *Analysis of Variance on the use of Training Providers by Business Sector*

Frequency of use of Training Providers	Business Sectors																		F-Value	Signi-ficance
	Manufacturing			Construction			Financial and Business Services			Transport & Communication			Commerce			Others #				
	N	Mean*	SD	N	Mean*	SD	N	Mean*	SD	N	Mean*	SD	N	Mean*	SD	N	Mean*	SD		
External consultants / vendors	20	3.35	1.14	6	4.00	0.63	42	3.69	1.20	8	3.63	1.41	11	3.64	1.29	7	4.14	0.69	0.64	0.67
Human Resource professionals	18	2.56	1.20	6	2.33	0.82	41	2.07	1.19	8	2.00	1.07	13	2.77	1.30	7	3.29	1.11	1.92	0.10
Department / functional managers	19	2.79	0.85	6	3.67	1.03	43	3.30	1.30	8	3.38	0.74	14	3.57	1.22	7	3.29	1.38	0.99	0.43
Academic professionals	19	1.84	1.07	6	2.33	0.82	42	2.29	1.24	8	2.25	1.04	13	2.08	1.04	6	2.67	1.63	0.64	0.67

Table 3. *Analysis of Variance on the use of Training Duration by Business Sector*

Frequency of use of Training Duration	Business Sectors																		F- Value	Signi-ficance
	Manufacturing			Construction			Financial and Business Services			Transport & Communication			Commerce			Others #				
	N	Mean*	SD	N	Mean*	SD	N	Mean*	SD	N	Mean*	SD	N	Mean*	SD	N	Mean*	D		
Less than 1 day	17	3.24	1.35	4	3.00	1.63	38	3.16	1.44	6	2.33	1.37	9	2.89	1.45	6	2.50	1.52	0.59	0.70
1 day to less than 3 days	18	3.78	1.00	6	3.83	1.17	37	4.05	1.08	7	4.14	0.90	12	3.75	1.22	7	4.14	0.69	0.36	0.87
3 days to less than 1 week	17	3.06	1.03	4	2.50	1.00	36	3.00	1.01	7	3.57	0.98	11	3.00	1.18	6	3.33	1.63	0.62	0.68
1 week to less than 2 week	17	2.24	1.30	4	2.50	1.29	36	1.92	1.13	6	2.67	0.82	10	2.10	1.20	5	2.60	1.52	0.73	0.60
2 weeks to less than 2 months	17	2.00	1.41	4	2.00	0.82	34	1.53	0.71	6	1.50	0.84	11	1.73	1.01	4	1.25	0.50	0.83	0.52
2 months to less than 6 months	17	1.76	1.09	4	1.50	1.00	34	1.41	0.82	6	1.33	0.52	10	1.30	0.48	4	1.25	0.50	0.62	0.68
6 months and above	16	1.69	0.95	4	1.50	1.00	31	1.29	0.53	6	1.00	0.00	9	1.11	0.33	4	1.00	0.00	1.85	0.11

* *1 = Least Frequently Used. .....5 = Most Frequently Used*

Includes companies from the healthcare, theatre and performing arts, IT and printing services.

Table 4. *Analysis of Variance on the use of Training Evaluation Methods by Business Sectors*

Frequency of Training Evaluation Methods	Business Sectors																		F - Value	Signi-ficance
	Manufacturing			Construction			Financial and Business services			Transport & Communication			Commerce			Others #				
	N	Mean*	SD	N	Mean*	SD	N	Mean*	SD	N	Mean*	SD	N	Mean*	SD	N	Mean*	SD		
Surveys/questionnaires	14	4.07	1.14	6	4.17	0.98	19	3.89	1.15	6	4.17	1.17	7	3.00	1.15	4	4.50	0.58	1.35	0.26
Supervisor feedback	13	3.38	1.19	6	3.83	0.75	18	3.61	1.09	5	3.60	0.55	7	4.00	0.58	4	4.50	0.58	1.01	0.42
Administration of tests	14	2.57	1.40	4	1.75	0.50	16	1.88	0.96	6	2.83	1.17	7	2.29	0.95	3	2.00	1.00	1.13	0.36
Trainer feedback	12	2.83	0.94	6	3.50	1.52	17	2.82	1.07	6	4.17	0.41	7	3.00	1.00	4	4.00	1.15	2.37	0.05

* *1 = Least Frequently Used .....5 = Most Frequently Used*

\# Includes companies from the healthcare, theatre and performing arts, IT and printing services.

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