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A

Discursive and Cognitive Reorganization
Through Training on a New Technology

by

Elena Zazanis

A dissertation submitted to the Graduate Faculty in Psychology in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York

1996

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Abstract

Discursive and Cognitive Reorganization
Through Training on a New Technology

by

Elena Zazanis

Advisor: Professor Katherine Nelson

This study explored the relationship between language and thought in conceptual development among adults in a workplace where a new inventory control and production planning technology (MRP) was about to be implemented. Subjects were employees in a transportation remanufacturing facility in which their responsibilities included managing, planning and executing the repair and maintenance of public transportation vehicles.

The first phase of the study consisted of ethnographic observation and detailed pre-training interviews which probed for existing concepts of production and scheduling. This phase was followed by a training workshop that engaged trainees in constructing novel MRP concepts and re-organizing existing production concepts within the MRP conceptual domain. Post-training interviews measured discursive and cognitive change surrounding target MRP concepts on the problem solving tasks presented in pre-training interviews.

The theoretical foundation for the study was grounded in Vygotskian theory, and the premise was that language plays a bi-directional role in adult conceptual development in terms of mediating new concepts and reflecting internalized and integrated knowledge. A methodology was developed for investigating this relationship, and a model for the relationship between language and thought in adult conceptual development emerged.

Discourse content and structure surrounding MRP problem solving activities were analyzed and compared with non-verbal performance in pre- and post-training interviews.

Results indicated that terms mediated new concepts and that terms were stated before underlying concepts were fully integrated. At first trainees used existing production knowledge to scaffold the new MRP concepts. MRP concepts were then isolated from pre-existing knowledge for internalization and integration. Qualitative changes in discourse structure surrounding the MRP conceptual system occurred with conceptual integration as non-verbal performance on problem-solving activities advanced. Finally, trainees who could consider production constraints and realities in implementing MRP strategies for problem-solving had reached the coordinated level.

Acknowledgements

This project was supported and encouraged by my advisor, Katherine Nelson, whose groundbreaking research in child language, memory and conceptual development has inspired students and faculty around the world. Although this study departed from her immediate interests, her open mind found a place for my work, and her contribution to it is immeasurable. Her insights are reflected throughout, and I would like to express my deepest gratitude to her for so closely supervising this project.

Without Joe Glick, this research would not have been possible, as he salvaged the Laboratory for Cognitive Studies of Work after Sylvia Scribner passed away, and reshaped the research program to accommodate the three remaining members, Lia DiBello, Jessica Kindred and myself. He led the new Laboratory for Cognitive Studies of Activity by facilitating us in designing a research program that extended and refined the theoretical paradigm within which we had been working. His guidance enabled me to stretch my potential to the maximum.

I am forever indebted to Katherine Nelson and Joe Glick for their patience and for believing that I could accomplish this project. They set examples of excellence for which I will strive throughout my life.

My sincere and deep appreciation goes to Vera John-Steiner for her rigorous review of my dissertation proposal and critical analysis of the work in progress ever since. Her research on private speech has been an underlying inspiration in this project. I cannot thank her enough for accommodating my every need from such great distance.

I extend many thanks to Jessica Kindred for her comments and critiques, as well as the intellectual balance she provided to the project. I must also thank Lia DiBello, with whom I conducted all training workshops and interviews.

This dissertation is dedicated to my parents, George and Marina Zazanis, who have granted me the opportunity to pursue this endeavor, knowing and teaching me that there is no greater benefit than an education.

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CHAPTER 1.

INTRODUCTION

The goal of this dissertation is to examine the relationship between language and thought in conceptual development among adults in a workplace in which a new inventory control and production planning technology (MRP) was about to be implemented. Previous studies of employees working in manufacturing environments who had already developed MRP and traditional manufacturing knowledge inspired the inquiry toward the development of MRP knowledge and the coordination of multiple conceptual systems in the workplace. Here the attempt was to refine an existing Vygotskian theoretical paradigm, and to advance the methodology for analyzing discourse from this theoretical perspective. First, in this paradigm, language is seen as a communicative and representational system; in other words, it is seen as both a reflection of information and systemic relations, and as having mediational and informational functions. I assume that discourse is a reflection of cognition in some contexts and a formative tool in others. Therefore, I devised an experiment to test hypotheses about when and how discourse refers to the broader realm of what people know, and when and how it changes that knowledge or actually mediates new information.

While existing developmental theory and research inform this inquiry, the nature of the adult subject requires special consideration, not only with regard to the construction of new knowledge, but to the reorganization of existing knowledge, as well. Vygotsky (1988) theorized that conceptual development involves the integration

of pre-symbolic, spontaneous concepts with symbolically mediated, formal concepts. Further, Vygotsky and his followers (see Wertsch, 1985a, 1985b, & 1981) constructed a paradigm for the development of higher mental functions. In this framework culturally organized activities with culturally constructed tools lead to higher mental functions relevant to the socio-historic context under observation. Thus, for adults who possess formal concepts and higher mental functions within a particular domain, social and technological change imposes two types of cognitive demand: one involves the construction of new concepts and mental activities and the other involves the reorganization of existing - in certain instances overlapping and in others diametrically opposed - concepts and mental activities. In this paradigm language is seen as an essential tool employed by individuals to negotiate new interpretations of objects and events in collaborative activity. An investigation of discourse in the process of this kind of negotiation is really an inquiry into the way the use of language can modify existing formal concepts in addition to mediating new concepts.

In previous research by the Laboratory for Cognitive Studies of Activity (Scribner & Sachs, 1991; Scribner, Dibello, Kindred & Zazanis, 1992; Zazanis and Glick, 1993), analyses of interviews conducted with workers in several manufacturing plants yielded results that pointed to structural differences in discourse surrounding different domains of knowledge. Specifically, two domains of knowledge within the same plant were observed to be encoded distinctively, to the point that these "languages" of work domains operated in certain ways like different languages in bilingual communities. Two specific conceptual systems emerged from our

observations and interviews as related yet distinct. One we called the production conceptual system, the classic concepts and terms of manufacturing goods from raw materials to finished products, managing the resources (equipment, transportation, space) required to support the process and insuring the quality of the finished goods. The other we called the MRP conceptual system, the concepts and terms surrounding a new technology that was implemented to control inventory through scheduling work and purchase orders. These previous studies, however, could render less than optimal insights into developmental issues, as they were conducted in contexts where the data sampled reflected what had already developed in terms of multiple conceptual systems. Nonetheless, these studies provided the foundation for designing research that would track the development of "bi-conceptualism" and the role of language in the process.

Bilingualism and Bi-conceptualism

In previous work (Zazanis, 1992), I adapted linguistic tools for analyzing bilingual code-switching (the switching back and forth between conventional languages in bilingual conversations) to shifts between knowledge systems in conversations. The analyses of MRP and production knowledge that I conducted on the interviews of workers who were working in plants that had already implemented MRP were designed to measure the degree of balance between the two systems, based on Poplack's (1980) analysis. Poplack has hypothesized that intra-sentential switching (code-switching within a minimal subject-predicate proposition) is an

indication of bilingual balance. All talk by workers interviewed was segmented into propositions which were then coded for production and MRP content. Propositions were grouped into MRP and production "streams" (sequences of propositions), and proportions of streams, frequency of switching between streams and frequency of switching within propositions were compared among individuals within a plant and between groups in different plants. Balanced knowledge of the two systems reflected in the switching correlated significantly with analyses of semantic content and performance on card sorts in terms of the quality of groupings.

While this scheme was successful for analyzing "fossilized" knowledge, new measures were sought to analyze emerging knowledge systems. As Wertsch (1985) stated, "form reflects transformations undergone and factors entered into development;" the interesting route to take now is to discover how the "form" takes form.

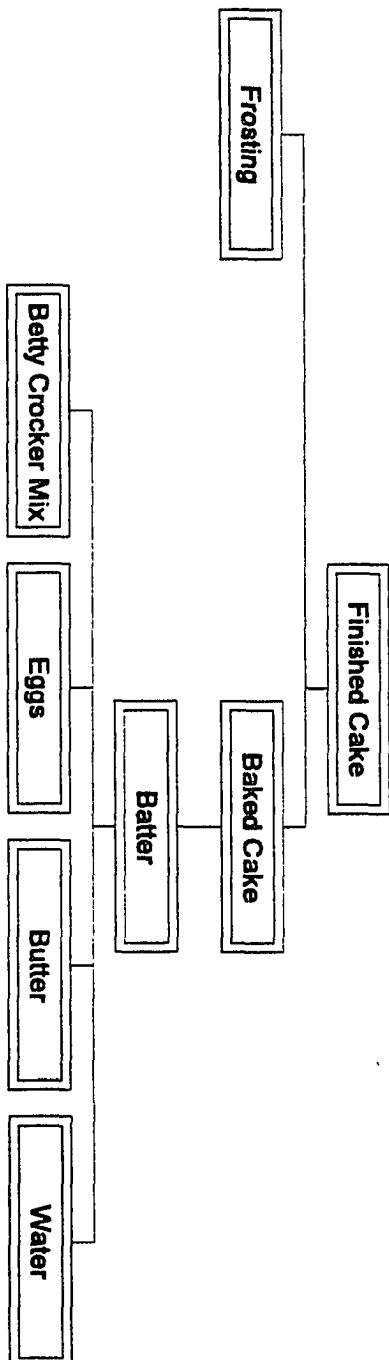
What is MRP?

MRP is a technology implemented in manufacturing and re-manufacturing environments to effect inventory reduction and increased efficiency in scheduling work and purchase orders. A work order is a request for some physical activity to be completed such as an assembly, a repair, an operation, such as plating or soldering, and so on. A purchase order is a request for material requirements, such as raw materials, purchased assemblies or buy items, operations conducted outside the plant, and so on. The concepts and logic underlying MRP for scheduling work and purchase

orders are often counter-intuitive to individuals with practical experience in manufacturing and re-manufacturing.

From the traditional manufacturing and re-manufacturing (henceforth, production) perspective, a product is made from raw materials into finished goods. Work and purchase orders are made with respect to a master schedule which is derived from a forecast based on histories of customer orders, contemporary factors pertinent to the industry, and many others, as well. The master schedule generates due dates and work and purchase orders are made toward those dates. Thus, from the production perspective, orders are planned from the present into the future. Furthermore, the master schedule usually involves all items produced in the plant. In other words if a factory makes cars, all the components will have requirements from the master schedule, including the wheels, the doors, the engine, the subcomponents of the engine, to name the very fewest. As inventory levels fall, pre-set minimums signal the requirement for more; as inventory levels rise, pre-set maximums signal requirements for less. (The min-max system is not universal, but it is common.)

Figure 1. Cake Item Structure



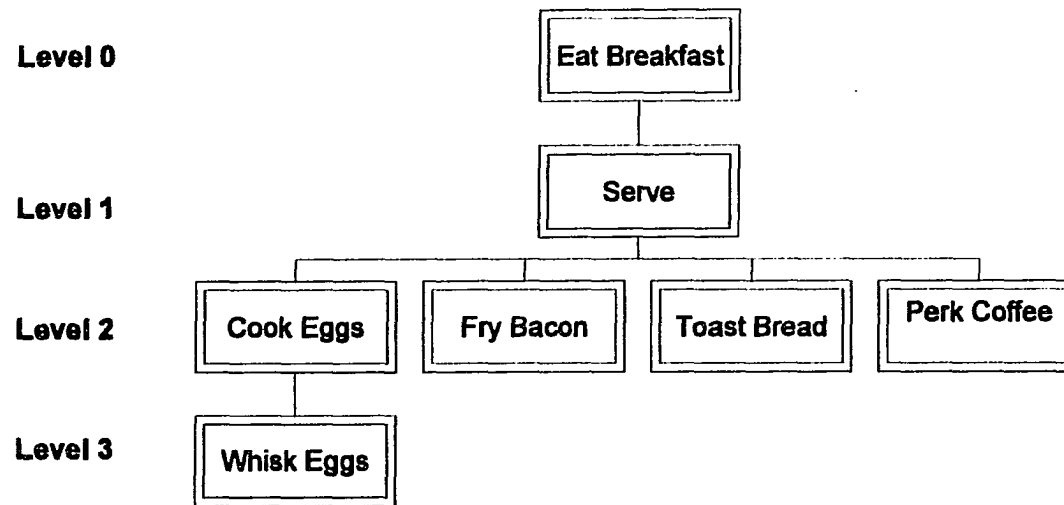
MRP logic considers a finished good in terms of a hierarchy, with parent-child relationships between all components and the finished good, or end item. This hierarchy is called an item structure and is the first key concept in understanding MRP logic. Instead of considering production as a process from raw materials into finished goods or from unrepaired to repaired items, MRP logic demands that the finished good be considered from the top down. That is, the end item (produced or repaired) is at the top of the hierarchy and subcomponents are organized into levels subordinate to the end item. Imagine a cake made from a packaged cake mix. In Figure 1, notice the levels on the right. Level zero is the finished good or end item, and each level is redundant on the level above it. At level three, cake mix, eggs, butter and water will combine to form batter, which is the next level up, and so on. At level zero, there are no higher levels.

The next key MRP concept is virtual quantity. From the production perspective, quantities of inventory items are independent from the item(s) and/or finished goods with which they will ultimately be assembled or replaced. With MRP, all items can and must be linked to one or more higher assemblies, lower assemblies, repair parts, and so on. The "bill of material" in MRP is essential for these links. Quantities are ordered based on need generated from the end items. Lower level items are not entered into the master schedule. Therefore, quantities are not triggered by a min-max system; rather, quantities are demanded by higher level items which ultimately inherit demand from the top end item, down. Quantities of any item are drawn first from unallocated on hand inventory. Once on-hand inventory is used, MRP will recommend

that a work or purchase order be released, depending on whether the item is a make or a buy item.

Finally, MRP does not release orders based on meeting a future due date. MRP logic requires that work and purchase order be scheduled from the future due date back toward the present. Hence, if the master schedule contains 200 widgets in July, the MRP system will recommend an order for the last operation to be executed just in time to meet the due date. In this way all items exist in a hierarchy, and all items have "lead times" associated with them. Lead time is the amount of time required for an item to be purchased or made. When MRP concepts of time and item structure are integrated, the MRP scheduling strategy, or "time phasing" results. Time phasing is often more common in everyday activity than it is in manufacturing. Imagine cooking a typical, bacon-and-egg breakfast. If you are a good chef, you will not start everything at the same time; rather, you will finish everything at the same time in order to serve all the food hot. Figure 2 illustrates a time phased plan for cooking breakfast.

Figure 2. Time Phasing Breakfast



MINUTES	Lead Time	1	2	3	4	5	6	7	8
Serve	1 min							X	
Cook Eggs	3 min				X	X	X		
Whisk Eggs	1 min			X					
Fry Bacon	5 min		X	X	X	X	X		
Perk Coffee	6 min	X	X	X	X	X	X		

MRP is a theory instantiated in a software system, a theory that cannot be applied without the computer as the calculations are too burdensome for human beings. Although it is a very powerful technology, an MRP system cannot run production. People must consider its recommendations against factors that MRP does not account for, such as quality, machine efficiency, unpredicted independent demand, etc. A system that is running well is doing so because the people that it affects and that affect it understand how it is coordinated with the "production."

The two systems, MRP, and the less abstract and practical system of production, have been analyzed as domains of organized, but structurally different, knowledge. While MRP is closed, production is open and infinite. Furthermore, MRP represents, in a particular way, only a part of the world of production – that is, MRP only considers the aspects of production in which material is involved. Production, on the other hand, is a huge enterprise involving sales, interpersonal relations, personnel hierarchies, market/industry, to name only a few that are not even remotely considered by the MRP system.

Why MRP?

The choice to track MRP concept development was based on several factors. First, I had previous research experience with this technology and could draw on that to develop the present study. Second, the opportunity arose to enter a site before its implementation began, thus affording a window into the development of MRP knowledge. Third, MRP is an ideology of production; it is an abstraction on the

production system with a bias toward "just in time" rather than "just in case." The language surrounding the MRP and production systems are distinct in content and structure. Experience from the previous MRP studies enabled me to draw concrete and specific hypotheses about the relationship between language and thought in MRP conceptual development within the Vygotskian paradigm.

However, while previous studies investigated the language and problem solving strategies of workers engaged in MRP and production activity in the workplace, the present study considers the language and problem solving strategies of trainees before and after an MRP training workshop. Thus, the subjects in this study are in the process of developing MRP concepts, while those subjects interviewed in previous studies had "fossilized" knowledge of MRP. Furthermore, the subjects from previous studies had developed their MRP and production conceptual systems through a combination of formal training, apprenticeships and various on-the-job activities, whereas trainees in the present study had no on-the-job experience with MRP. From an activity theory perspective, the present study is qualitatively different than previous studies in the sense that the training workshop has been the only sphere of activity within which trainees had the opportunity to engage in constructing MRP concepts. The goal of the present study is to track the use of MRP language and concepts constructed through the activity-based training workshop. The method developed for the present analyses was derived from Vygotskian theory on the relationship between language and thought and enhanced by methods borrowed from discourse analysts for discovering implicit and explicit knowledge revealed on several levels of discourse.

The Relationship Between Language and Thought

Information and systemic relations are always located in a given activity sphere (i.e., a human culture within a specific history). In other words, the role that language ostensibly plays in the relationship between language and thought relies heavily on the theoretical assumptions behind the origins of mental process. If all forms of mental reflection, from rudimentary to higher levels, are conceived to have their roots in biological structures, then the relationship between language and thought will lie within the boundaries of the brain. On the other hand, if the mind is considered to be an emerging product of the ongoing interaction of biology, the physical world, and the interaction among human beings moving through history, then the relationship between language and thought is more complex, yet more important, as language is one of the select mediational forms that has the capacity to import and export semantics among individuals acting in society.

The issues surrounding language and thought have been debated through several models that examine language and thought from different perspectives. These models can be categorized into distinct positions (Nelson, 1989), including cognitive determinism, linguistic determinism, linguistic and cognitive equivalence, and finally, the dialectical model, where language and cognition are interdependent.

If we look at cognitive determinism, it becomes apparent that this is a model of the necessary processes for higher mental functioning. Without the mechanisms articulated by Piaget (1974), for instance, an individual would be unable to employ language for the analysis of experience; through the process of reflective abstraction,

an individual develops the ability to construct logical structures based on interaction with the environment. Now the problem is that the environment consists of universal and culture-specific phenomena. Furthermore, culture-specific phenomena (i.e. language, music, rituals, everyday practices, work, etc.) are usually those created by a group of people throughout their history, and thus contain a great deal of information not only in their explicit content but also in their implicit structure.

Cognitive determinism overlooks the importance of language as a mediational device. If language and cognition operate as two interactive streams (Nelson, 1989), cognitive processes explain only one side of the dialectic. Therefore, the value of cognitive determinism lies only in its insights into cognition. Language, on the other hand, is pervaded by implicit structures and categories that select a paucity of the potential information available to an individual. There are some theorists who have suggested (indirectly) that language is thought. For instance, Nelson points out that the classic case of this is behaviorism, where thought is simply silent speaking; she also notes Fodor's (1975) explanation that language maps onto the internal "language of thought," which consists of a system of concepts – these concepts are innate, and they are triggered when language is acquired. Nonetheless, if language is believed to trigger innate concepts, it must still be recognized that the language of a community selects which concepts are triggered.

Consequently, the role of language is significant in every model. It is simply framed differently. In Piagetian and Fodorian models, language and cognition exist more or less internally. The mind generates cognition, and the central argument

among these theories is whether or not cognitive structures are innate. Language is considered to follow or reflect those structures. On the other hand, theories that consider the role of language to be more (or most) significant attribute external influences on the individual with more significance, as well. While there is a relationship between language and thought within the boundaries of an individual, if language is to play any role in that relationship, the nature of language must be understood outside of those boundaries.

Within the dialectical model language evolves in a cultural milieu, where ideas and activities are woven into the structure and content of semiotic systems. People appropriate words and linguistic strategies to reflect their attitudes and intentions, which are then communicated to others. Language also mediates attitudes and intentions which have evolved over time. People borrow the system, transform it and return it to posterity in novel form. As this occurs repeatedly over time, a language takes on the characteristics of its respective culture. Therefore, it would be impossible to understand the dialectic between language and cognition within the individual without understanding all that language imports from the external world.

For [Wittgenstein], to imagine a language truly is to imagine an entire form of life; the set of representational (and instrumental) devices and the mode of their deployment in everyday activities...In a sense, all knowledge is relative, but also that objectivity is not in direct competition with relativity...The symbol-enriched form of life lived by any social group forces encounters with a finite

number of aspects of the natural and artificial world, never with all possible aspects (Bullock, p. 193).

Thus, language can shape conceptual thought to the extent that it becomes difficult to access non-verbal concepts, such as perceptual, imaginal or procedural thought. In conjunction with this line of thinking, Bullock asserts that "the brain truly is a device of prodigious potential, but it remains a mere lump of protoplasm unless it's involved in the kinds of interactive behavioral cycles that allow its internal states to actualize their potential representational statuses" (p. 197). He holds that intelligence is as much a product of these interactive modes as it is of "structural potentials" or "having a suitably plastic brain" (p.199). Inherent in this statement is the importance of language in the interactive mode, as, contrary to popular belief, language is not the "mere outward garb of thought" but rather that the "presumptive representational paradigm and the potential reference rub up against each other" (Bullock, p. 209) – it would be otherwise impossible to create, let alone understand, a new metaphor.

Paralleling Wittgenstein's assertion that language constrains the individual to a "finite number of aspects of the natural and artificial world," Whorf, his predecessors, and his followers have claimed that cross-linguistic investigations reveal how different grammatical structures encode different sense relations (Lucy, 1985). Lee (1985) has argued that the Whorfian perspective is instrumental in understanding how different languages lead to different folk theories through grammatical relations and

metaphorical expressions. The Whorfian position holds that structures in language are instrumental in mediating to the individual how to classify experience. While Whorf leans toward a position of linguistic determinism, examining the theory affords us deeper insight into the role of language in the language/thought dialectic (John-Steiner, 1991).

The goal of this dissertation is to examine the relationship between language and thought among adult subjects in the process of developing new MRP knowledge. The Whorfian model sets forth the notion that the structure and content of language shape thought and logic. In order to test this empirically, a developmental design is necessary. Without any evidence for how an individual arrives at a given perspective, the origins of that perspective are only theoretical. Thus, a perspective or conceptual system about to be developed must be located. For analytic purposes, linguistic and non-linguistic representations are isolated. Repeated interviews with the individuals in the process of developing this conceptual system will then lend insight into whether 1) language is a container that follows from logic and thought or 2) the language surrounding the system is leading through mediation.

Internalization, Externalization and Mediation

Concerning the questions of process and development in language and thought relations, Vygotsky and his followers took a leading role. Vygotsky separated psychological phenomena into categories that apply to all humans and animals and that apply exclusively to humans (Wertsch, 1985). Cultural and higher cognitive

functions are strictly human and are mediated through the socio-cultural milieu, while natural, elementary functions are the product of biological forces. Furthermore, Vygotsky held that theorists cannot apply explanatory principles of elementary functions to higher ones. Vygotsky's criteria to distinguish between elementary and higher mental functions are:

- (1) the shift of control from environment to the individual, that is the emergence of voluntary regulation;
- (2) the emergence of conscious realization of mental processes;
- (3) the social origins and social nature of higher mental functions;
- (4) the use of signs to mediate higher mental functions (Wertsch, p. 25).

Elementary functions are completely dependent on environmental stimulation; higher functions are generated by creating and using artifacts. Furthermore, realizing or being conscious of these higher mental functions also distinguishes them from elementary ones. Insofar as the stimuli are concerned, the environmental forces are given universals that exist physically, but tools and signs are created by humans and become automatized in the process of repeated use, thus increasingly less reliant on the context in which they were conceived (Wertsch, 1985).

Vygotsky's (1986) investigations of language development revealed the child's progress toward integrating language and thought as one with its origins in social interaction. In this view, language is at first social, where speech is employed to communicate what the child is discovering to be referential to objects in the world as well as internal feelings. Gradually, the child begins to direct her own activities

"intrapsychologically" with the same mediational devices (language) that were originally interpsychological. At first, this self-guiding use of speech is spoken aloud, thus Vygotsky placed a different interpretation of purpose on what Piaget (1959) had called egocentric speech. Further, Vygotsky claimed that with more difficult endeavors, the child's egocentric speech increases, serving a heightened referential function. Finally, egocentric speech is internalized and functions as inner speech, which is hypothetically abbreviated speech, representing the basic units of thought, which for Vygotsky are word meanings.

What is significant about Vygotsky's theory of language development for the purpose of this project is the concept of internalization (and externalization) of self-guiding media. Though much of the focus of Vygotsky's theory has been placed on internalization, there is an equally important construct of externalization that is evidenced not only in children but throughout the life-span, particularly in instances of microgenesis and complex problem solving tasks. Talking to self as audience in absentia or even presence of others is common (John-Steiner, 1992). Employing mediational devices originally used in interactions, to direct one's own behavior is a significant part of adult mental functioning. In fact, much technology represents a medium that is not only externalized but disowned.

Certain tools and signs are internalized, decontextualized and automatized, potentially liberating mental effort for expenditure on increasingly higher levels of mental functioning. On the other hand, some technological tools and artifacts are employed to extend, systematize and store information, processes and relations

between objects with which human beings have been previously burdened. Some examples are books (which extend memory), calculators (which extend problem solving processes), the best example being the computer (which extends human memory and even human mental functions, such as planning and decision making). Of course, no technology is intelligent in its own right (at least not yet); in fact, any technological innovation is meaningless in absence of human interaction. Nonetheless, Vygotsky's characterization of technology as "artificial" extension of human capabilities suggests that tool and sign mediation is complex and multi-directional (Bruner, 1990).

Tikhomirov (1979) has expounded on Vygotsky's notions of "artificial" mental functions extended by computers.

By translating the formal components of activity in the solution of a problem into the form of an external mediating chain, the computer makes it possible to reveal and develop the intuitive components of thought and the chain of the generation of hypotheses, since the complexity of the task verifying these hypotheses often, as it were, overwhelms the intuitive components of thought. The results of the analysis that has been conducted allow us to state that even on a functional plane, changes occur in the intellectual processes of a person solving complex problems in conjunction with a computer (p. 276-277).

Vygotsky claimed that any new developmental path deserves new explanatory principles (Wertsch & Stone, 1985). Tikhomirov frames the new stage of computer-

aided mental function as a new form of mediation whose effects must be considered both on inter- and intrapsychological planes.

...how the computer changes the structure of human intellectual activity. Memory, the storage of information, and its search (or reproduction) are reorganized. Communication is changed, since human communication with the computer, ..., is a new form of communication. Human relations are mediated through use of the computer. Of course, the computer creates only the possibility for human activity to acquire a more complete structure. Such possibilities are realized only when certain technical, psychological and social conditions are found. The technical condition is that the computer must be adapted to human activity, and the human must adapt to the conditions of working with a computer. The main conditions are social – what the goals are for which the computer is used in a given situation...reorganization of human intellectual, mnemonic, communicative and creative activity as a result of the use of a computer's functional possibilities and coordination of human activity with the use of tools (p. 277).

Hence, the computer, as a technology that extends "artificial" mental functions, requires the individual to reorganize "natural" mental functions. This line of thinking is significant to a study on workers' acquisition of a computer system that regulates their work processes and generates recommendations for plans and problem-solving.

Work evolves through increasingly sophisticated inventions, (although, like people, inventions can also go through U-shaped development, getting worse before they get better). The changes that incur in mediational devices originate from mental reflection on activity that, circularly, was mediated by tools and signs. Through internalization and externalization, abstractions of practical activity change activity, itself, and in turn change mental reflection.

Conceptual Systems

While the discussion up to this point has been focused on the side of language, "thought" has been modeled in many ways, as well. For the purpose of this dissertation, the kind of thought investigated was characterized as conceptual systems, and the premises on which this characterization are based consider conceptual systems to be mediated reflection on activity. The quality of conceptual systems depends a) on whether mediation has been formal or empirical, and b) on the degree to which an individual has formed an integrated, cohesive representation of the domain.

People, even from a very young age, represent and reflect on experience holistically and not as independent details. People build expectations from experience that make interpretation of novel events possible, yet all the while, existing expectations when unmet by encounters with novel events, are modified and reorganized. This is reflected in the literature on event representation, all suggestive of "frames" (Bateson, 1972; Hymes, 1974; Goffman, 1974), "schemata" (Chafe, 1977;

Rumelhart, 1975) or "scripts" (Schank & Abelson, 1976; Nelson, 1986) as integrated representations of experience in propositional, imaginal and procedural form, as opposed to elemental units. Frake (1977) has captured the role of context in an analogy of building expectations or scripts in many domains to map-making as a developing set of principles that overlap, intertwine and develop interactively, as opposed to a set of static, cognitive maps. A Piagetian perspective on constructing knowledge through assimilation, accommodation and equilibration is necessary but insufficient to investigators of developing conceptual systems; the importance of mediational form and context is tantamount.

In empirical investigations of differences in individual knowledge representations, Gobbo and Chi (1986) conducted a study on how knowledge is structured and used by expert and novice children in the domain of dinosaurs. They claim that the structure of novice and expert knowledge differs in that experts demonstrate the use of integrated, cohesive knowledge of their domain of expertise, while novices operate with independent and unrelated conceptual units in the same domain. Their evidence for this characterization of expert/novice differences in knowledge structure was derived from linguistic and non-linguistic measures of performance on recall and categorization tasks. All children were asked to render information about 20 illustrations of dinosaurs on cards and also to sort the cards in logical groupings.

Talk was segmented into propositions and then coded for content, connectives, semantic comparisons, over-arching themes and judgement of dinosaur's class

membership. Hence, analyses were employed to measure 1) how knowledge was structured and 2) how knowledge was used. The type of information coded was both explicit (what could be obtained from the pictures) and implicit (what was unavailable from pictures and thus had to have been represented in pre-existing knowledge). Interestingly, not only did experts produce more implicit knowledge, but the mode of presentation was more integrated, manifested by use of connectives such as if, then, but. Furthermore, the card sorts correlated with the verbal performances in the sense that groupings were based on logical and analogical strategies as opposed to novice groupings based on surface structure and explicit pictorial features. This study is extremely relevant to the present proposal for it paves the way for analysis of knowledge systems through linguistic and non-linguistic performance. Furthermore, the use of connectives is among a plethora of linguistic indicators of schematic knowledge.

Discourse Analysis

Just as any other form of human behavior, discourse can be analyzed from many different perspective. Some analysts focus on the social dynamics manifested in exchanges between interlocutors, while others consider the cognitive structures reflected in speech. Hodge and Kress (1988) present a framework for analyzing semiotics in negotiations of power and solidarity. Although Hodge and Kress are primarily concerned with the socio-political implications of communication in various semiotic forms, they have set forth a theory of levels which separates within

communication the negotiation of meaning from the negotiation of social relationships. From their perspective, there are always two planes of communication; one plane is the "mimetic," which Hodge and Kress reserve for the content of communication. The other plane is named "semiotic," on which discourse is used and manipulated in negotiating power and solidarity.

Discourse markers in the form of modal operators (modals, generalizations, hedges), connectives (temporal, disjunctive, causal, conditional) and the like are described and exemplified in this section. They can be analyzed as tools on both mimetic and semiotic planes, and discourse analysts have approached these tools from both perspectives. As mentioned above, Gobbo and Chi found a significantly higher distribution of connectives in experts' discourse surrounding the domain of their expertise compared with novices' discourse surrounding that domain. This is an example of an analysis of the mimetic plane of discourse. Other researchers, such as Schank and Abelson (1977), have approached the mimetic plane for analysis, as well, articulating modal operators that reflect underlying "scripts" or "schemas" for events or domains of knowledge. I categorize these analyses of discourse as "mimetic" because they do not undertake to discover the individual or group differences in use of discourse markers that leads to gaining or losing power in negotiations.

On the other hand, discourse analysts have been committed to understanding the way in which different groups or individuals manipulate (or are manipulated by) discourse and discourse markers in negotiations of power and solidarity on the "semiotic" plane. For example, in Tannen's (1994) recent work on gender differences

in discourse, she finds that the expression of uncertainty through discourse markers like the "hedge" is more prevalent among women than men. An example of a hedge is "sort of," as in, "This paper is sort of confusing." On the semiotic plane, one interpretation may be that the speaker is not entirely confident one way or the other about the clarity of the paper or about actually making a judgement. This can lead to the speaker's subordination in the conversation at large. However, on the mimetic plane, the content communicates that on a continuum of clear to confusing, the paper is in the middle, reflecting the speaker's experience and ability to draw this relative judgement against others.

The present analysis focuses on the mimetic plane of discourse in developing MRP concepts, as the object of inquiry is really the role of language in mediating and reflecting new concepts in development, rather than the relationship between interlocutors through discourse surrounding these concepts. A study relating more closely to the differences among individuals and independent variable groups in using new MRP concepts in order to negotiate their positions as "insiders" or "outsiders" in the system would involve an analysis of the semiotic plane of discourse.

In her earlier work approaching the mimetic plane, Tannen (1979) reviewed and employed a host of measures to discover schemata underlying explicit discursive representation. Below is a description of the linguistic devices Tannen tracked to locate schemata in discourse.

Omissions. Knowing a priori the critical elements of a domain makes it possible for a researcher to search for linguistic structures that reflect integrated and cohesive

schemata. Omission (Schank & Abelson, 1977) of a sub-event in a narrative, such as not mentioning the silverware in a restaurant "script," indicates that in general, a great deal of information about events is not represented in discourse, although, clearly it must be represented in cognitive context as a necessary element in the event. In fact, the missing objects or sub-events taken for granted among interlocutors are sometimes among the most essential of objects or sub-events within an event.

Backtracking. On the other hand, Tannen points out that "backtracking" may result from the subsequent (to one or more propositions) realization that an object, sub-event or element in the event cannot go unexplained for discourse to make sense.

Repetition. Another linguistic structure is repetition (Labov, 1972), which may reflect emphasis to highlight a key element in the schema.

Connectives. As mentioned above, Gobbo and Chi found connectives such as so, if and then, to reflect integrated knowledge structure.

False Starts. Finally, Tannen claims that false starts can indicate the incident of an unmet expectation from schematic representations.

While these linguistic structures reveal insights into generalized event representations, there are also linguistic devices that speakers strategically employ to actually take advantage of common schemata for negotiating meaning.

Hedges. An example of this type of device is the hedge (Tannen, 1979), (such as 'sort of' and 'really') which measures the instance of an object or element at hand against a prototype.

Modals. Another example is the modal (Labov, 1972), where inference is indicated

in light of a particular event compared to the generalized representation. (For instance, 'he must have, should have, may have, etc. paid the bill at the restaurant).

Contrastive Connectives. Contrastive connectives (Lakoff, 1971) make use of the prototype or schema in a similar way in the sense that conflict with the implicit schema is represented to convey a particular instance. (We went to the store 'but' didn't buy!)

Generalization. One of the most commonly measured indicators of schemata is the generalization which refers to the use of timeless and unspecified agents, (as in, 'you' get to the restaurant).

Non-Syntactic Anaphora. Similarly, non-syntactic anaphora (Gensler, 1977) points to the inferred schema without explicating it, as in 'if we had uniform part numbers, it may work,' where 'it' refers to inventory control.

Evaluative Language. Finally, evaluative language (Labov, *ibid*) can be employed to measure attributes of objects or elements in the instance of an event against the prototype. An example of this is 'very sophisticated system,' where the prototype of system is less sophisticated than the one at hand.

The above discursive forms or markers reflect what I now think of as "cognitive support," or the individual's self-scaffolding strategies for making sense in communication by drawing on personal experience, (i.e. connectives, generalizations, modals, omissions, hedges) and shared references or concrete and readily available cues in physical presence (i.e. backtracking, non-syntactic anaphora). One purpose of this dissertation is to investigate and tease apart the complementary roles that

language plays as both a mediator of novel concepts and a reflector of existing ones. Tracking the discursive markers associated with production and MRP domains through pre- and post-training is hypothesized to reflect specific pattern in development: the proportion of discourse markers associated with existing knowledge should be much greater than that associated with unfamiliar and developing concepts. In this developmental study, concentrations of discourse markers in talk surrounding the new conceptual system, MRP, are expected to increase as individuals internalize and integrate new MRP concepts. In other words, while MRP terms and discourse in training will mediate the new conceptual system, discourse marker concentrations will be a reflection of the internalization process. Higher discourse marker concentrations are thus hypothesized to reflect concepts that are well on their way in the proposed microgenetic process.

Hypotheses

From an activity theory orientation (Davydov, 1985; Leontiev, 1979), an individual internalizes spontaneous activity, culturally organized activities and practices, language and other semiotic forms. The individual can then manipulate internalized structures either via inner speech or by externalizing those structures in semiotic or physical forms of activity. Development is a continuous process of internalization and externalization. Therefore, the history of the knowledge systems, the forms through which they are mediated and the individual's existing knowledge schemata must all be considered when undertaking to discover the discursive consequences of a microgenetic experience.

The hypotheses are as follows:

1. The development of the new MRP conceptual system will be characterized by the internalization of new terms and concepts, as well as the integration of the concepts within the MRP system. Mental activities will follow the internalization of socially mediated terms and concepts. At first, trainees will attempt to map the MRP system onto their existing production knowledge. As discrepancies and counter-intuitive concepts are encountered between the two systems, they will be isolated. Once the MRP concepts are internalized and integrated, the two systems can be coordinated.
2. As the mediated terms and concepts are internalized, the need to talk aloud through problem-solving activities will decrease (much in the way Vygotsky

characterized the internalization of speech among pre-school aged children and thus the disappearance of egocentric speech).

3. The internalization of and integration within the MRP system will begin with terminology. New MRP term use will lead concept development.

4. In problem-solving activities, the use of MRP concepts in speech will run ahead of the implementation of MRP strategies.

5. While discourse content will reflect the mediational role of language, discourse structure will reflect conceptual achievement. Naturally, trainees will make use of "cognitive support" from the production system before acquiring MRP concepts. The production system will also scaffold incipient MRP concept development. While the MRP conceptual system begins to be isolated and internalized, there will be a decrease in production talk and the discourse markers surrounding it. As conceptualization of MRP takes place, cognitive support will develop and will be reflected in an increased proportion of discourse markers surrounding discourse with MRP content.

CHAPTER 2.

METHODS

Setting. The data collected for this dissertation was obtained from a training program implemented in a remanufacturing organization within the transportation sector of New York City. Specifically, two shops in this transportation agency, the pneumatic shop and the electric bench, have operational responsibility for maintaining an essential city service by providing preventative maintenance and running repairs to some 6,000 highly complex and multi-part vehicles which come in about nine to ten basic varieties. The shops are both civil service and unionized. There are approximately 300 employees in the two shops, and permission to conduct this research was obtained from both management and union representatives.

The training program, further detailed in this section, involved three phases: 1) Pre-training Interviews; 2) The MRP Workshop; and 3) Post-Training Interviews. Interviews and workshops were conducted by researchers from the Laboratory for Cognitive Studies of Activity. Before interviewing began, researchers spent two weeks at both shops "shadowing" and conversing with volunteers from three categories of the workforce (mechanics, analysts, and management). A fair degree of familiarity was established between researchers and trainees. Even if we had not spent a significant amount of time with each trainee before pre-training interviews, our presence and activities had been established as non-threatening and impartial research, which would serve to inform "the university" about technological transitions in manufacturing environments. Furthermore, all trainees volunteered to participate in the training

program. All trainees were informed that interviews and workshops would relate to the MRP implementation and that the workshop, itself, would be a two day seminar involving a simulated manufacturing game. For many of our volunteers, our workshop was their only formal introduction to and training on the MRP system about to be implemented.

After some debate, MRP had been purchased by this transportation agency as a technological strategy to combat dangerously high inventory levels. The pneumatic shop and the electric bench were the two shops where the MRP implementation would begin. Those opposed to the purchase of MRP had argued that MRP was designed for manufacturing plants and that MRP was inappropriate for a re-manufacturing plant within the transportation agency. However, a meta-analysis of inventory levels conducted in the Laboratory of Cognitive Studies of Activity during the initial observational stage of the research program, revealed that the agency's inventory problems reflected the same dynamic as those of traditional manufacturing plants. Essentially, this agency had defaulted to the same manufacturing/re-manufacturing universals that ultimately led to the pervasive implementation of inventory and production control technologies, first in Japan and then in the US during the 1980's. That is, items that seem most essential for production or repair were ordered excessively "just in case" of emergency, although they may have comprised the most expensive and/or perishable sector of the entire inventory profile. On the other hand, all items, even the least costly, were not associated with each other in terms of subassemblies and finished goods. Therefore, the "just-in case"

approach led to overstocking of certain items, yet shortages in others, halting an entire production line due to the shortage of a two cent item. Furthermore, interviews and observations revealed that the mechanics, who were ultimately responsible for meeting a shop floor schedule, were given no window into the long term schedules for overhaul and scheduled maintenance programs, let alone a feedback mechanism to inform those responsible for planning shop floor activities. Therefore, mechanics were privately stocking parts in lockers and under benches "just in case, as well. Mechanics, analysts and management would all be affected by the MRP implementation. Whether or not the outcome would be positive rested on the acceptance and integration of the system among the better part of the employees affected, as repeatedly reported in the literature on countless MRP implementations around the country (Wasco, Stonehocker, & Feldman, 1991; Maloney, 1990)

There are four categories of re-manufacturing at the site, including overhauls, scheduled maintenance, running repairs and emergency repairs. The electric bench and pneumatic shop are the areas in which major repairs are made. They supply the "barns," or satellite shops, with replacement parts. When the vehicles within a particular fleet are entirely disassembled and rebuilt with upgraded replacement parts, it is an overhaul. The major operations of an overhaul are executed by the electric bench and the pneumatic shop. Scheduled maintenance is systematic replacement of components in a vehicle at specific intervals. The schedule is informed with the history of breakdowns for the most frequently replaced parts. The idea is to replace these

parts before they break and ultimately reduce running and emergency repairs to a bare minimum. Scheduled maintenance activities are conducted in the barns; however, the electronic bench and pneumatic shop provide the barns with parts and receive from the barns materials for remanufacture. Running repairs involve the replacement of broken components on vehicles that can still make service. While the vehicles are held in the barn for cleaning, service or some scheduled maintenance operations, those which require "running repairs" are maintained. Finally, emergency repairs occur when a vehicle breaks down while in service and cannot continue the route. The responsibilities of analysts, mechanics and managers relate to these programs in the following ways.

The role of analysts is to support these programs with schedules for material and labor. In order to develop and distribute the schedules, the analysts engage in research surrounding histories of material requirements for scheduled maintenance programs, and for supplying the barns with materials for running repairs. Changes in government safety regulations, product engineering, vendor policies and relationships are also considered by analysts, in addition to new technologies, such as MRP, for supporting the scheduling activities.

Mechanics are mainly responsible for disassembling, cleaning and remanufacturing the components which are ultimately transported to satellite shops for replacement into transportation vehicles. Mechanics are not expected to plan work and purchase orders nor to consider costs, material availability or consequences of high inventory levels or other work flow issues. Mechanics are not provided with long

term schedules generated by those responsible for procurement, scheduled maintenance and overhaul planning. Instead, mechanics receive a daily schedule.

Depending on the level and specific domain, managers' responsibilities range from overseeing the physical activity on the floor to coordinating the budget for an overhaul program. The most senior managers attend to labor and material costs and ultimately endorse or reject the projected schedules of the analysts. The chief supervisor of the plant envisioned the MRP implementation as a transition toward a better integrated and more efficient organization. At first, there had been no plans to train mechanics; however, together with the analyst who spear-headed the MRP project, we made several arguments for training as many mechanics as possible.

If mechanics started using MRP, they would have a window into the longer term schedules for the shop floor. This would enable the mechanics to anticipate work and trust in the availability of required items, heading off the "hoarding" problem. In addition, mechanics who can understand MRP concepts and coordinate them with the reality of the shop floor, can provide important feedback to the MRP system, as well, both at the point of data entry and at the point of generating schedules. Mechanics have direct knowledge of how items are disassembled, cleaned, repaired and reassembled. The closer the MRP system is to reflecting the "real world," the more successful its implementation (Wasco et al., 1991); therefore, mechanics would be an important resource in both informing and maintaining the MRP system.

Figure 3.

Job Title

Distribution of Trainees in Mechanic, Analyst and Management Positions

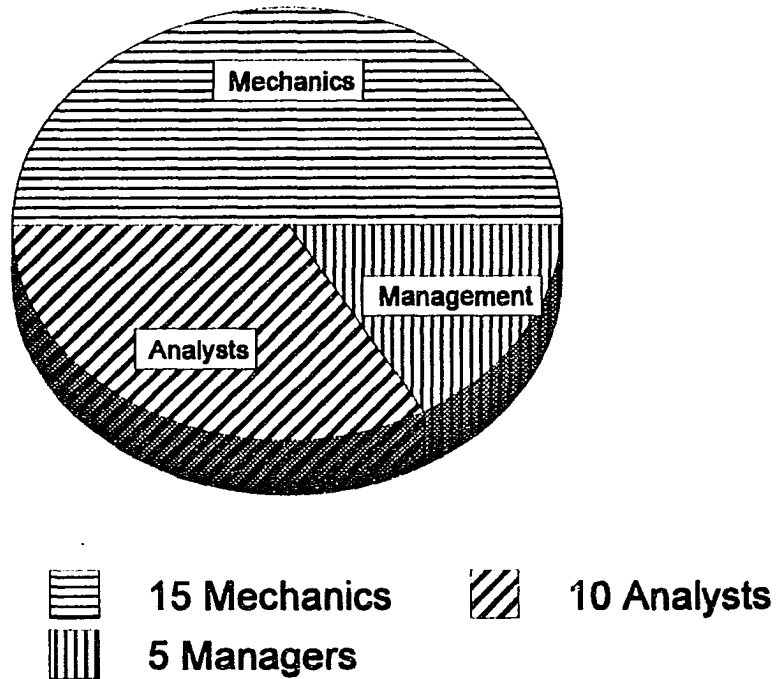


Figure 4.

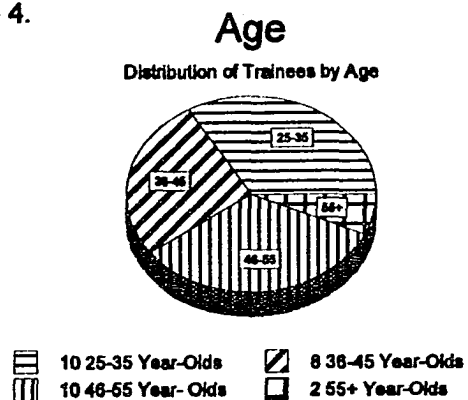


Figure 5.

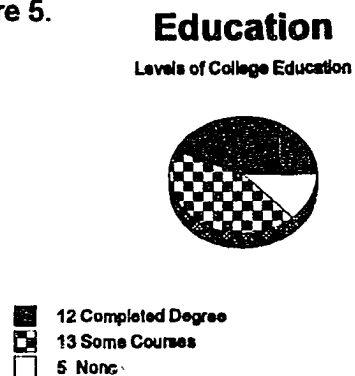


Figure 6.

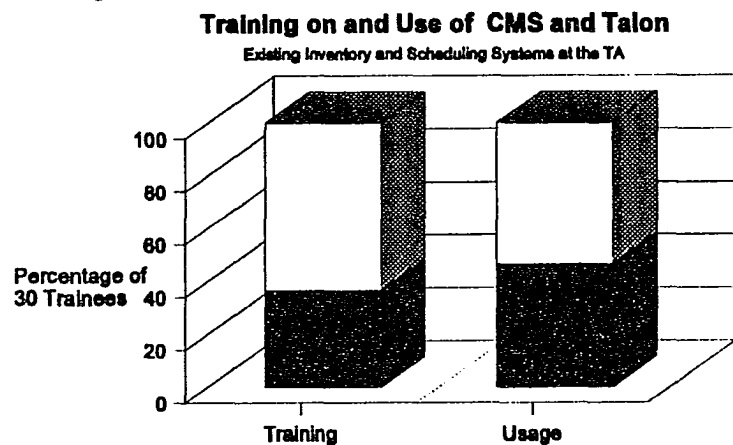
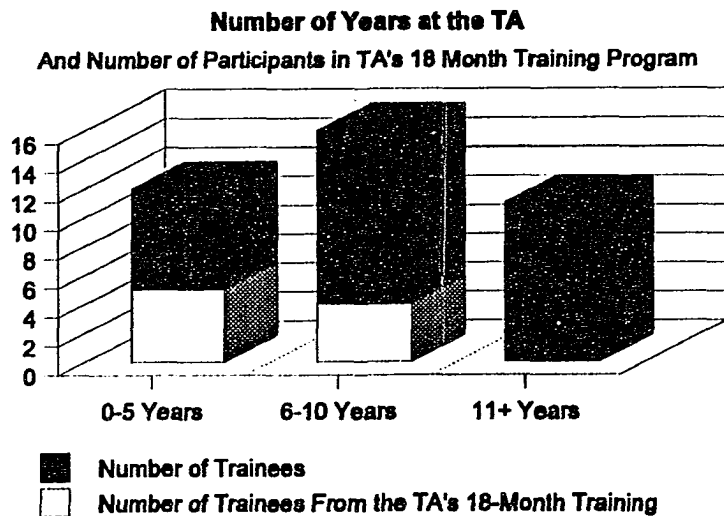


Figure 7.



Subjects. Figure 3 displays the number of participating trainees in each job title. Figures 4 through 7 present the distribution among these trainees in age, college education, training on and usage of existing inventory and production control technologies and participation in an 18-month in-house training program. The technologies already implemented for inventory and production control were called CMS and Talon. These systems allow for rudimentary bills of material, describing all items in inventory and generating on-hand quantities for each; however, none of the existing technology reflected the complexity in item structures or the comprehensive scheduling strategies of the MRP technology.

For instance, "bills of material" (BOMs) in CMS consisted of part lists for higher assemblies. MRP BOMs are organized hierarchically with redundancy of parts on each level; notice in Figure 1 on the lowest level, the four items (Betty Crocker, water, eggs, butter) are represented again but in a different "phase" on the next level up, level 3, as batter. In CMS, the cake BOM would have been written as a list of water, eggs, butter, Betty Crocker, and frosting. Furthermore, neither CMS nor Talon empower analysts to schedule work and purchase orders as linked to the final product, or end item in the way that MRP generates time-phased schedules from a future due date back toward the present. Therefore, these existing technologies were not expected to endow those who used them and/or had been trained on them with isomorphic MRP concepts before our training workshop. However, the demographic analyses were not limited to isolating MRP-like concepts in pre-training interviews. The reason

for considering all of these variables was related to their significance in explaining both pre-training and post-training differences in verbal and non-verbal performance.

The 18-month, in-house training program, for example, may have provided some item structure concepts, or, more importantly, participation in the program may have pre-disposed trainees to conceptualizing abstractions of practical aspects of remanufacturing. The 18-month training program involves a combination of classroom and apprenticeship activities which prepare the trainees for various positions on the shop floor. The expectation is that once these trainees are placed in a given position as, for example, air brake maintainer in the pneumatic shop or "e-man" (a mechanic on the electric bench), they will have been prepared not only for that job but also to understand the relationship of their activities and materials with others as an integral link in the re-manufacturing and maintenance services of the organization as a whole.

Thus, age, educational history, technological experience and participation were considered in this dissertation in order to explain differences in existing MRP concepts before training and to explain varying degrees of conceptual achievement in post-training measures of MRP concepts. Previous research conducted in the Laboratory for Cognitive Studies of Activity yielded no significant support for these factors in explaining flexibility with MRP and production concepts (Scribner et al., 1992). However, in this study, the investigation was conducted with MRP trainees, none of whom had ever used MRP before. While results from previous research indicated that MRP and production coordination correlates with constructive activities on the system and not with factors such as educational history or job title, their relationship to

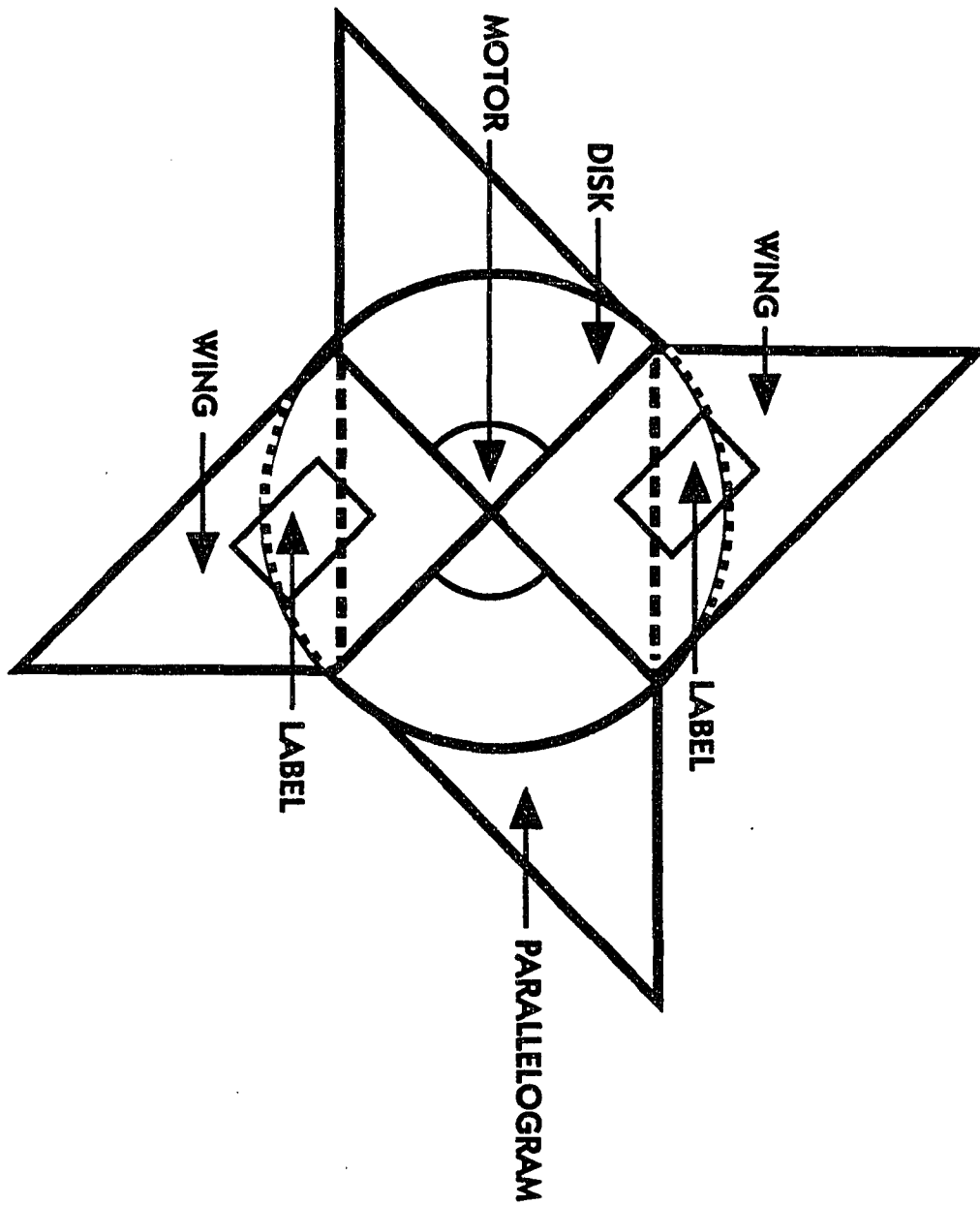
trainees' speed and depth in developing new MRP concepts may not be so easily dismissed. Taking more quickly to abstract technological concepts extrapolated from practical activities automatized after years of experience may be influenced by formal education or experience with other, even un-related, technological systems. The MRP game workshop was designed to afford trainees the opportunity to engage in constructive activities surrounding the MRP system – simulating the experience isolated by previous analyses to lead to MRP and production flexibility. Nonetheless, a survey administered to each trainee elicited these demographic variables in the pre-training interviews to determine whether or not the previous correlational findings were robust in the learning condition.

Training Workshop

The training workshop was organized to engage trainees in constructive activities designed to facilitate the conceptualization of core MRP concepts and operations. These two-day seminars involved a combination of game-playing with a simulated starship production factory, abstract concept building through physical activities carried out with starship materials, and formal lectures on MRP and supporting inventory concepts. Workshops were run on site by the Laboratory for Cognitive Studies of Activity, and trainees from five workshops were observed for this study. Held in the shop cafeterias and conference rooms, workshops were attended by an average of six volunteer trainees each. The workshop was originally developed by the president of the Tapanzee Chapter of APICS (American Production and Inventory Control Society). Researchers from the Laboratory for Cognitive Studies of Activity adapted the workshop for research, and refined it through pilot workshops. The aim of the workshop is to facilitate trainees in constructing three major MRP concepts and integrating them with existing manufacturing expertise. The three concepts are item structure, lot for lot quantity and time phasing. Previous research isolate these as generative of all other MRP concepts (Scribner et al., 1992).

The workshops are carried out as follows. Trainees are presented with workbooks and informed that they will be "taking" over a successful starship factory that has maintained a lean inventory and generated high profit margins. Trainers introduce three models of the basic starship (see Figure 8) and explain that these are the finished goods produced by the simulated factory. Trainees are presented with

Figure 8. The Starship



diagrams of the ship and tables containing information about the ship and all its components, including lead time, price and lot size (see Table 1). Trainers then distribute starship materials so that the new "factory owners" can practice assembling the ships. Trainees are briefed on the game's rules, material ordering procedures, and customer order procedures. Trainers then recommend that participants organize themselves into some suggested roles, (such as planner, assembler, game leader), and to familiarize themselves with the customer and purchase order forms (see Figures 9 and 10) and the procedures outlined in the workbooks.

Trainees then run their factory in 20 minute intervals which represent one week. They must build starships to customer orders and anticipate material requirements to arise in later weeks so that these order can be filled. Trainees begin with enough material on hand in a card board stock room to meet customer orders in the first two weeks; however, they should order materials in the first week for customer orders due in the third. If they don't recognize this, (which is almost impossible to do without making formal MRP calculations) they will fail to meet most customer orders after the second week.

Table 1.

PARTS, PRICES, AND LEAD TIMES

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PART#	DESCRIPTION	PRICE	LEAD TIME (WKS)	
000.10	STARSHIP, MODEL 1	\$110.00	1	ASSY
000.20	STARSHIP, MODEL 2	\$122.00	1	ASSY
000.30	STARSHIP, MODEL 3	\$150.00	1	ASSY
002.10	FOLDED PARALLELOGRAM	\$ 6.00	1	ASSY
001.10	BLUE DISK/MOTOR ASSY	\$ 72.00	1	ASSY
001.20	ORNG DISK/MOTOR ASSY	\$ 72.00	1	ASSY
001.30	RED DISK/MOTOR ASSY	\$ 96.00	1	ASSY
004.10	WING, SHORT, YEL	\$ 9.00	1	ASSY
004.20	WING, LONG, GRN	\$ 14.00	1	ASSY
003.10	DISK, BLUE	\$ 30.00	1	PURCH
003.20	DISK, RED	\$ 30.00	1	PURCH
003.30	DISK, ORNG	\$ 30.00	1	PURCH
003.60	MOTOR, NON-REMOV	\$ 42.00	3	PURCH
003.70	MOTOR, REMOVABLE	\$ 66.00	3	PURCH
009.01	LABEL: MODEL 1	\$ 2.00	2	PURCH
009.02	LABEL: MODEL 2	\$ 2.00	2	PURCH
009.03	LABEL: MODEL 3	\$ 2.00	2	PURCH
009.04	LABEL: MRP GAME	\$ 2.00	2	PURCH
009.05	STAPLES (PK OF 30)	\$ 30.00	1	PURCH
009.21	PARALLELOGRAM BLANK	\$ 4.00	1	PURCH
009.22	WING, SHORT, BLANK	\$ 2.00	1	PURCH
009.23	WING, LONG, BLANK	\$ 2.00	1	PURCH

FINISHED ASSEMBLIES/PURCHASE PRICES

001.10P	BLUE DISK/MOTOR ASSY	\$ 90.00	1	PURCH
001.20P	ORNG DISK/MOTOR ASSY	\$ 90.00	1	PURCH
001.30P	RED DISK/MOTOR ASSY	\$120.00	1	PURCH
001.40P	PARALLELOGRAM, FINISHED	\$ 10.00	1	PURCH
001.50P	SHORT WING, FINISHED	\$ 13.00	1	PURCH
001.60P	LONG WING, FINISHED	\$ 20.00	1	PURCH

Figure 9.

STARSHIP ORDER FORM

ORDER #: 8 ORDER WEEK: 8

PART#	DESCRIPTION	QTY	SEA	TOTAL	WK DELY
000.10	STARSHIP, model 1	1	110	110.00	
000.20	STARSHIP, model 2	4	122	488.00	
000.30	STARSHIP, model 3	3	150	450.00	

TOTAL: 4 1048.00

**PURCHASE ORDER**

P.O. NUMBER: _____

ORDER PERIOD: _____

PART NUMBER	DESCRIPTION	QTY	\$/U	TOTAL\$	L/T	DELY

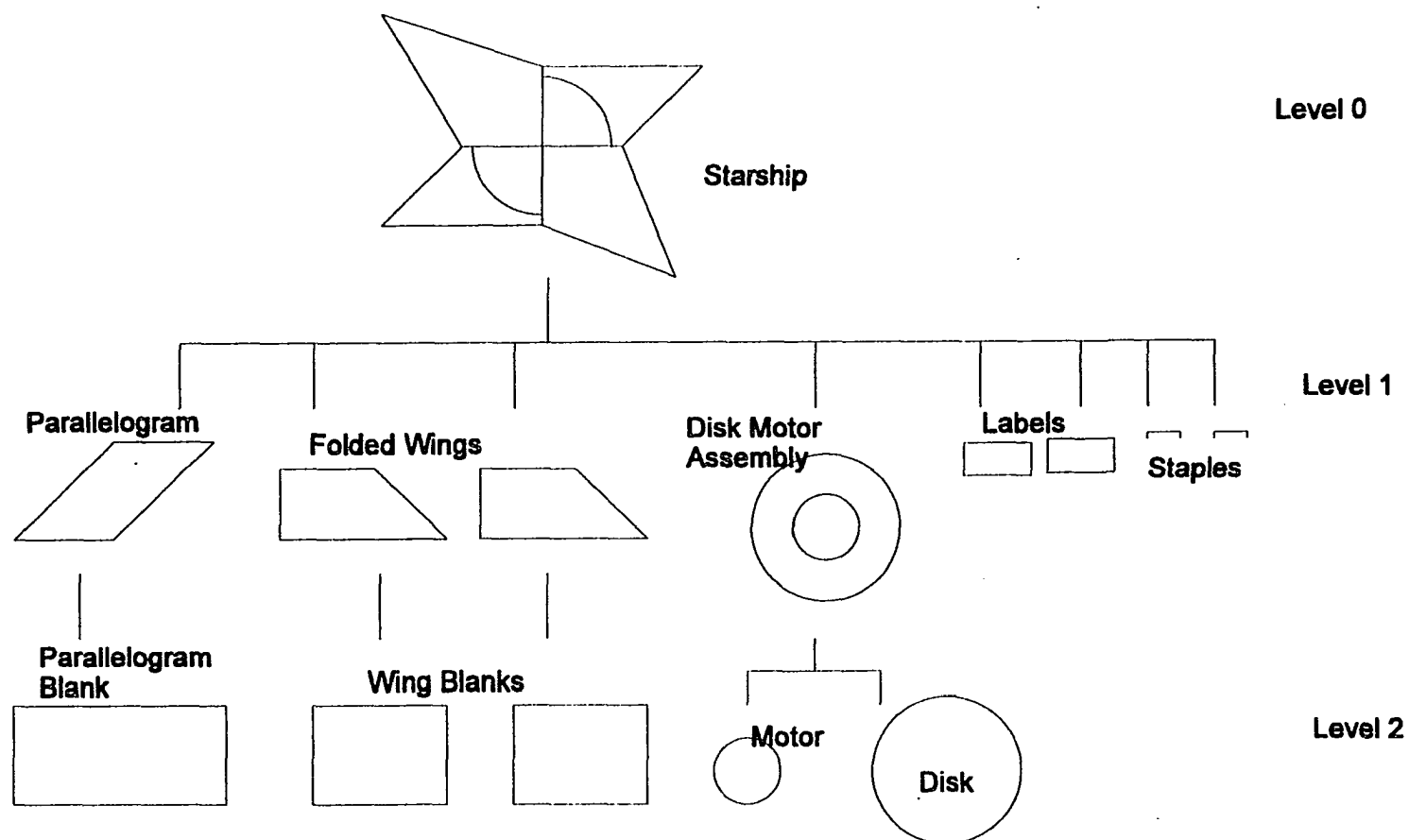
Usually during the third or fourth period, the subjects realize they are running into trouble and begin to devise strategies for getting themselves out. The stress of the time limits usually elicits "default" strategies, and it is at this point of the activities that subjects' work history becomes most evident. For example, shop floor workers attempt to deal with the crisis by accruing "critical" parts with their available cash. In addition, they attempt to step up and better organize production practices, so they can make more and better ships in less time. Importantly, this amounts to "cheating" on lead times established for each task. The main concern organizing their activity is getting the right number of quality ships to the customer, at all costs, rationalizing that if they don't produce, they won't make money anyway. They are more likely to borrow money from the vendor (at 20% interest per 20 minute period). In contrast, analysts, managers and other "office" personnel tend to try to solve the problem by controlling the budget and are less concerned with shipping on time than with going broke. They will make the customer wait, attempt to bargain with the vendor and sometimes take too long to make decisions about spending. In the end, by the time they decide what to buy, another "week" has passed and they have pushed back delivery even further. No group has prevailed in this phase of the training.

Trainers then stop the game and distribute a form that leads trainees to assess their starship factory's profits and losses. Then trainers initiate a discussion about what went wrong, what went right, how the starship factory may have been more successful, and most importantly, what parallels can be drawn from the starship experience to their own real work experience.

After this discussion, trainers present a slide show about MRP and inventory control. This lecture covers the MRP core concepts of item structure, lot for lot quantity and time phasing, and specifically introduces the ways that the system operationalizes these quantities in order to schedule work and purchase orders. In addition, inventory pitfalls are presented and strategies for inventory protection and organization are introduced. It is explained that these strategies are essential to a successful MRP implementation, as without the highest degree of inventory accuracy (when inventory quantities on record actually match physical inventory counts), MRP calculations lead to poor recommendations for work and purchase orders.

The next phase of the workshop involves a different kind of constructive activity than that of the starship factory. At this point pairs of trainees are given plenty of starship materials with which they are asked to make an item structure for the starship, based on the concepts of item structure/bill of material, level, and parent-child relationship, just presented in the lecture. They are asked to represent the item the way "MRP would represent a BOM." Each pair then presents their item structure to the rest of the group and explains the solution reached. At the end of this exercise, the workshop leader presents an item structure that is known to work well in an MRP system (see Figure 11) and asks the participants to compare it with what they did and discuss the differences.

Figure 11. Starship Item Structure



The trainees are then asked to actually begin setting up a manual MRP system, using forms that hold the data in a format similar (in terms of the functional logic) to what an MRP system would have. Trainees receive blank Bill Of Material forms (see figure 12), and Item Master forms (see Figure 13), and they must choose which items require an Item Master and which require a BOM. That is, what items the system needs to define, and how these items should be linked together. Trainees then translate the customer orders into a "Master Schedule" and decide where to put this information on the planning worksheets (Figure 14) directly underneath the Item Master File for each item. They must also decide which worksheets get the master schedule information.

The whole point is that, if MRP knows what goes into what, it only needs to know the demand for the finished goods, and will take over the calculation from there. Therefore, independent schedules should not be entered into the forms for the parts and subassemblies of the starship. Only finished goods should be associated with the master schedule, and this is what the trainees are forced to construct by completing the manual MRP schedules on the worksheets. Hence, trainees actually do the calculation that MRP normally does during a "regeneration" (the calculation of all work and purchase orders based on master schedule requirements and projected on-hand quantities). This includes putting in the "on hand" and "virtually on hand" quantities in the correct cells on the forms and doing the "explosion" down through all levels.

Figure 12.



MRP GAME BILL OF MATERIAL

PARENT PART NO. _____ LOW LEVEL CODE: _____

TYPE OF BILL () REGULAR () PHANTOM () PLANNING

PART NUMBER	DESCRIPTION	QTY



Figure 13.

ITEM MASTER			
ITEM # _____	DESCRIPTION: _____		
REV: _____	DRAWING # _____	LOW LEVEL CODE: _____	
LEAD TIME: _____	SAFETY STOCK: _____	LOT SIZE TECH: _____	SUPPLY PD: _____

Figure 14.

MRP WORKSHEET												
	1	2	3	4	5	6	7	8	9	10	11	12
REQ #1												
REQ #2												
REQ #3												
GROSS REQs												
SCHEDULED RECEIPT												
ON HAND												
PLAN ORDER RECEIPT												
PLAN ORDER RELEASE												

At the end of the regeneration, the "bottom line" (the Planned Order Release Recommendations at the bottom of each worksheet) represents MRP's recommended actions for all buying and building for each week. Trainees translate the planned order releases into a schedule for the starship factory and compare this to their performance in the first round of the game.

Pre- and post-training probes, described in the next section, were designed to measure the MRP concepts and operations constructed in this workshop.

Pre- and Post-Training Interviews. All trainees were interviewed immediately before the training workshop and at least six weeks and no longer than two months following the workshop for post-training performance. The interviews and workshops were all conducted by researchers from the Laboratory for Cognitive Studies of Activity and were held on site in conference rooms, sections of the cafeterias on off hours, or private offices. Appendix A contains a list of interview questions that comprise the pre- and post-training probes. The pre-training probes were designed to elicit maximum information surrounding work and educational history, responsibilities and goals of current position, the nature of the actual work in the current position, all mediational devices used, deficits of the work-place, global perspectives on the plant and any concepts that could be considered precursors to MRP knowledge. The post-training interview was designed to measure conceptual development, achieved in MRP and coordinated domains, and demonstrated in verbal and non-verbal performance. For the purpose of this study, the demographic data and verbal and non-verbal performances on two categories of problem-solving probes were analyzed. In the Lab's previous workplace research program involving MRP, two tasks had been designed to elicit MRP and production concepts and any coordination between the two. One was a card sorting task and the other was a scheduling problem. All discourse surrounding the card sorting and scheduling tasks was audio-tape recorded and later transcribed for analysis.

Card Sorting. The card sorting task, designed to probe item structure concepts, involves a multi-colored set of cards representing a finished good and its components

parts. The information on the top of the cards, (hand written in bold black pen) relates to the production domain, referring to an item's part number and giving an ambiguous description of that item, for instance "BRN ON BD" (brown on board). The information typed on the bottom of the card relates to the MRP domain and refers to an item's "relative level" and "used in" information. The trainee is presented with the cards and asked to arrange them in a way that represents how the finished good is made. The interviewers encourage trainees to talk aloud through the task. After the trainee completes the sort, the interviewer copies down the configuration of cards produced by the trainee (color coding facilitates this procedure) and asks if there is any other way the cards could be sorted.

In pre-training interviews, the cards represented a finished good and components from a hardware factory, pseudonymed Intek. Interviewers explained to the trainees that the Intek part should not look familiar and then debriefed them after sorting. The part descriptions are abbreviated and not easily interpreted. A trainee with a production bias would focus on this information, attempting to make sense of the descriptions and relate part numbers to each other. The trainees who focused on the MRP information 1) had either given up on making sense of the production related information and tried to make sense of "levels" and "used ins" or 2) had previous exposure to item structure terminology/concepts like "level" and attempted to sort the cards using the MRP information. A choice to use the MRP information, however, does not result in an MRP solution.

Figure15. A Typical Production Sort in the Intek Condition

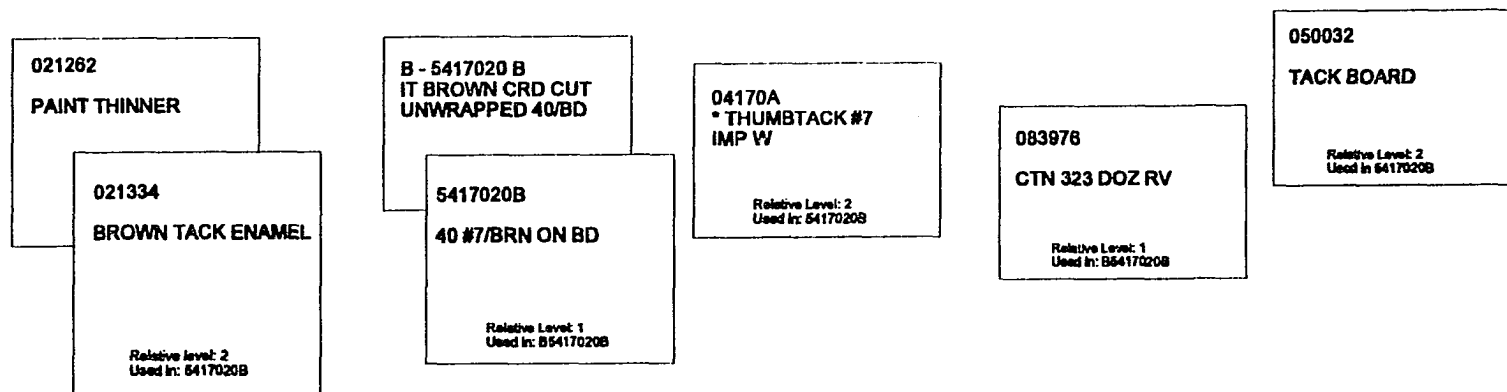


Figure 16. An MRP Card Sort in the Intek Condition

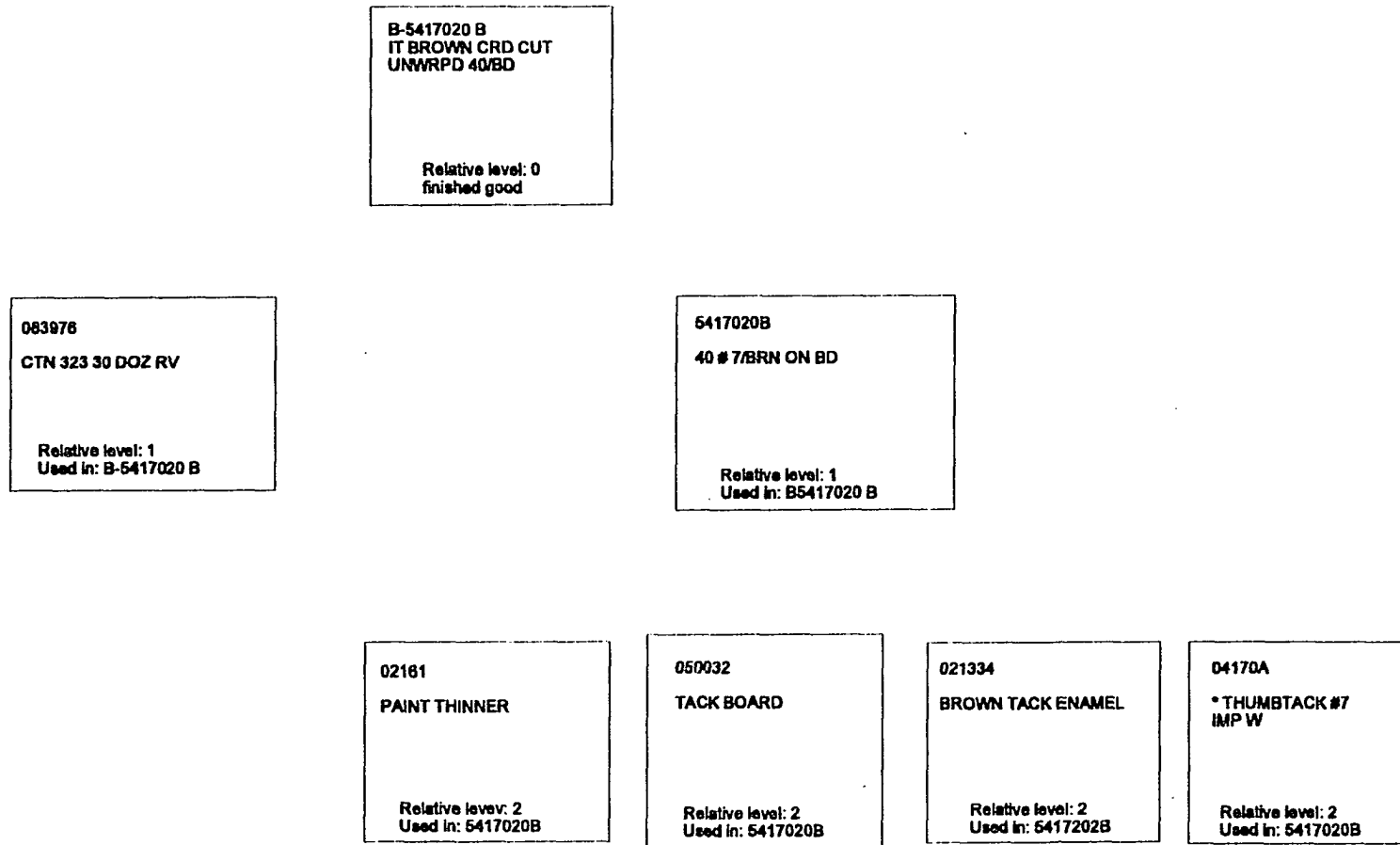
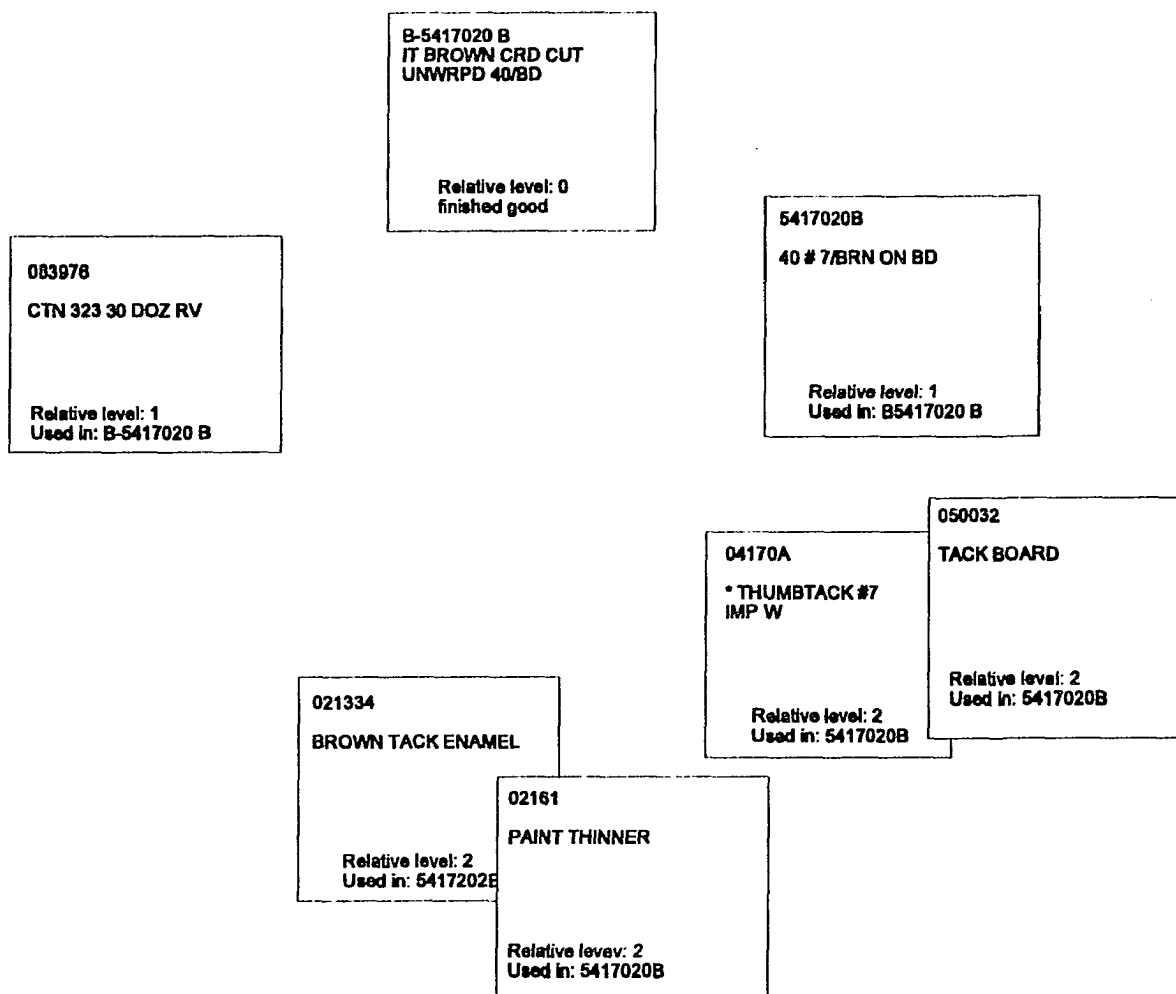


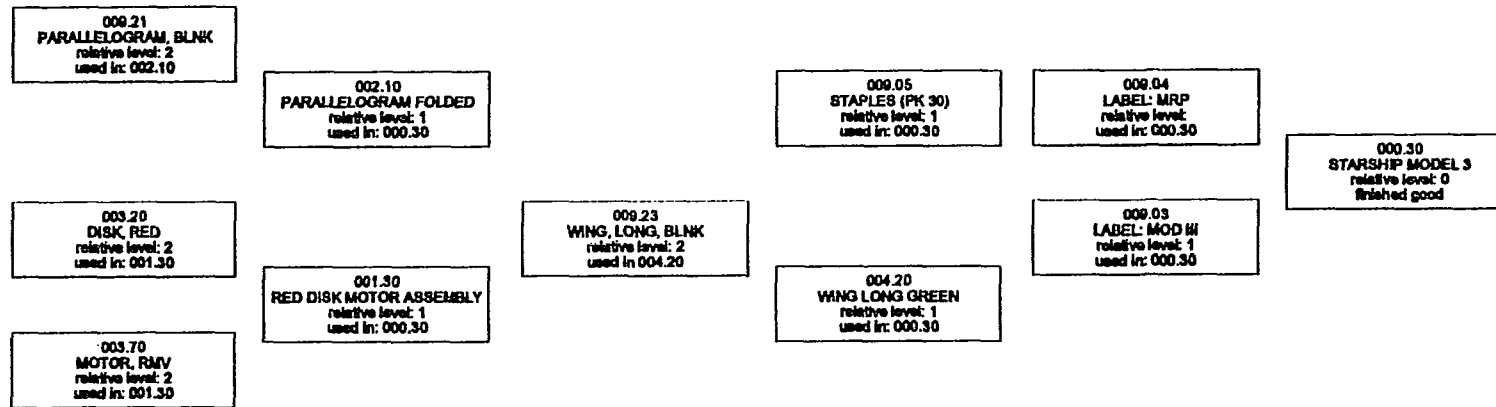
Figure 17. An MRP and Production Coordinated Sort for the Intek Item



Figures 15, 16, and 17 represent production, MRP and MRP/production coordinated sorts for the Intek item. In post-training interviews, trainees were presented with two card sorting tasks, the Intek sort (the same as the pre-training sort) and the "Ship" sort. The ship cards represented the finished good and components of the starship, which was the item used in the MRP game training workshop. Figure 8 displays illustrations of the starship, and Figures 18, 19 and 20 represent production, MRP and coordinated sorting solutions for the Ship sort.

Card sorts were scored on a scale of one to four. Those that reflected the production received a score of one. Production sorts are configured from a bottom-up or left-to-right orientation and begin with cards that the trainee has determined to be raw material, followed by subcomponents, and the finished good. The logic that is used to sequence the cards is based on transformational concepts, such as mixing paint or cutting board. MRP sorts, on the other hand, are oriented from the top down, starting with the finished good. Components are positioned underneath the finished good in descending order by level, and specific cards are placed directly under other, based on "used in" information. Transitional sorts reflect an attempt to make use of MRP information, yet fail to achieve the MRP item structure indicated on the bottom of the cards. Coordinated sorts combine MRP and production cues.

Figure 18. A Typical Production Sort in the Ship Condition



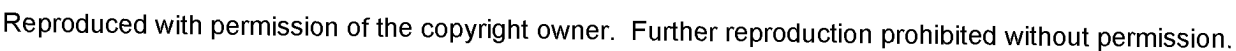
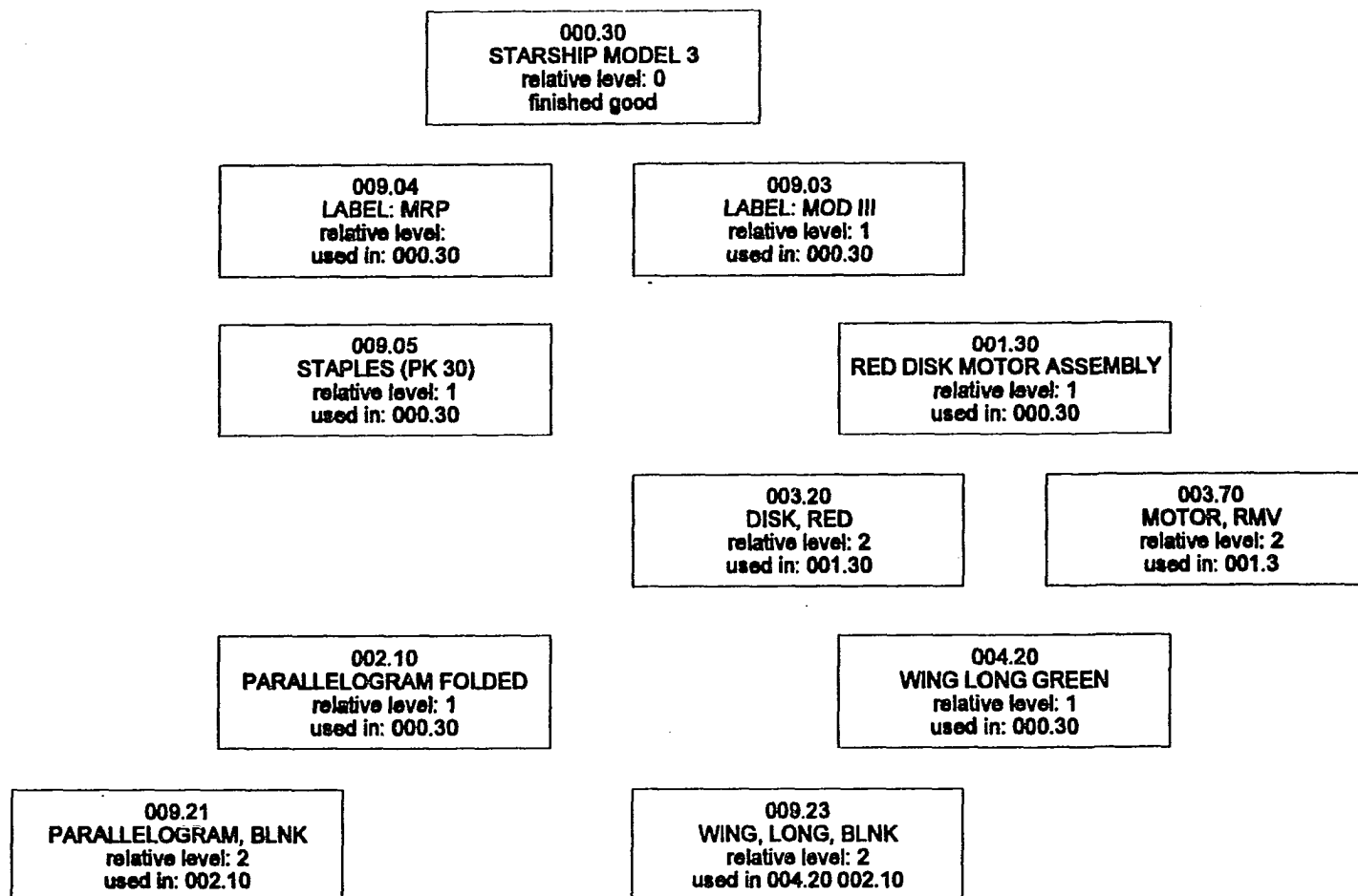


Figure 20. An MRP and Production Coordinated Sort in the Ship Condition

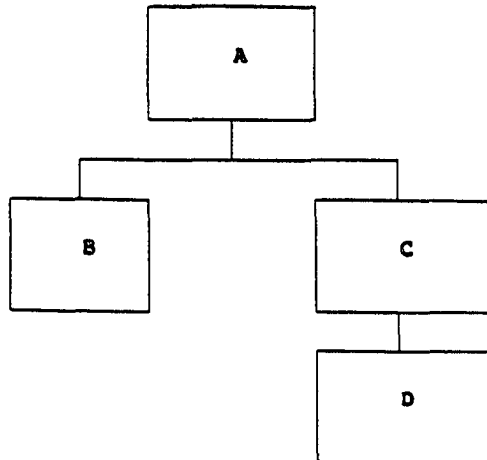


Scheduling. The second category of problem-solving tasks in pre- and post-training interviews was the scheduling question, designed to capture time-phasing concepts. In this task trainees are presented with a piece of paper containing an item structure diagram at the top for a finished good and its components, a table of information about the finished good and a calendar at the bottom. The task requires the trainee to schedule a given quantity of the finished good by a specific due date. The table contains information that constrains the scheduling possibilities, but the task could be executed from a production, MRP or coordinated strategy.

In the pre-training interview, the finished good "A" is the target. This abstract item has no concrete content; some trainees even assigned a "real" product to the "A," such as a bicycle or cork board. The "A" scheduling question is shown in Figure 21 exactly as it was presented to trainees. The item structure shows the relationship between "A" and subcomponents "B," "C" and "D," and the table gives lead time and quantity per information for each item. The goal is to schedule 200 A by August. In post-training interviews, trainees were given three scheduling questions, "A" scheduling redundant with the pre-training condition, "Ship" scheduling and "Pen" scheduling. (See Figures 22 and 23). The item to be scheduled in the "Ship" condition was the starship, used in the MRP game training workshop. While the "A" item was abstract, the starship was a familiar, concrete item, and used in actual MRP training. In the "Pen" condition, the finished good was a standard ball point pen, presented on another task earlier in the interview. The pen, although concrete and familiar as a writing utensil, was unfamiliar to trainees in terms of production experience.

Figure 21.

64

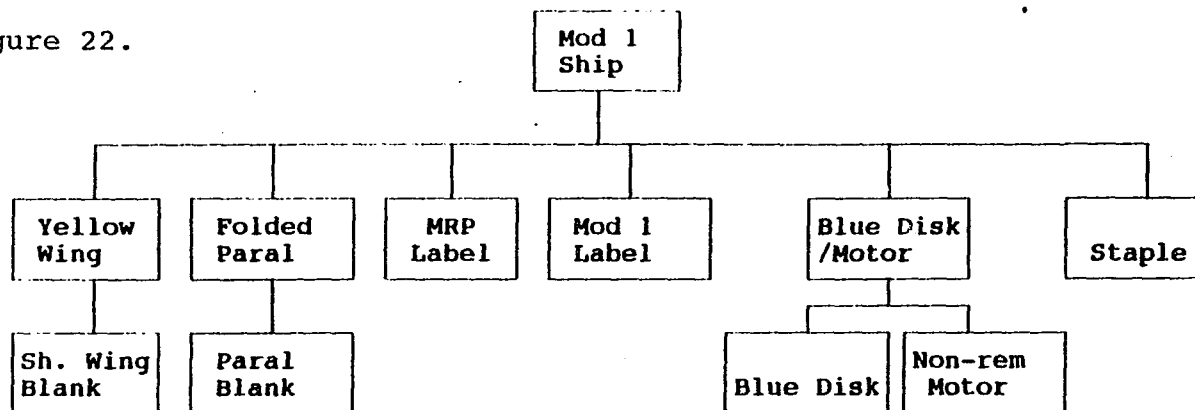


Item Number	Description	Relative Level	Lead Time	Quantity Per
A	A	0	2 months	
B	B	1	1 months	1
C	C	1	1 months	1
D	D	2	2 months	1

Schedule Item A and all of its components so that an order for 200 of the finished good A can be shipped in August.

jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec

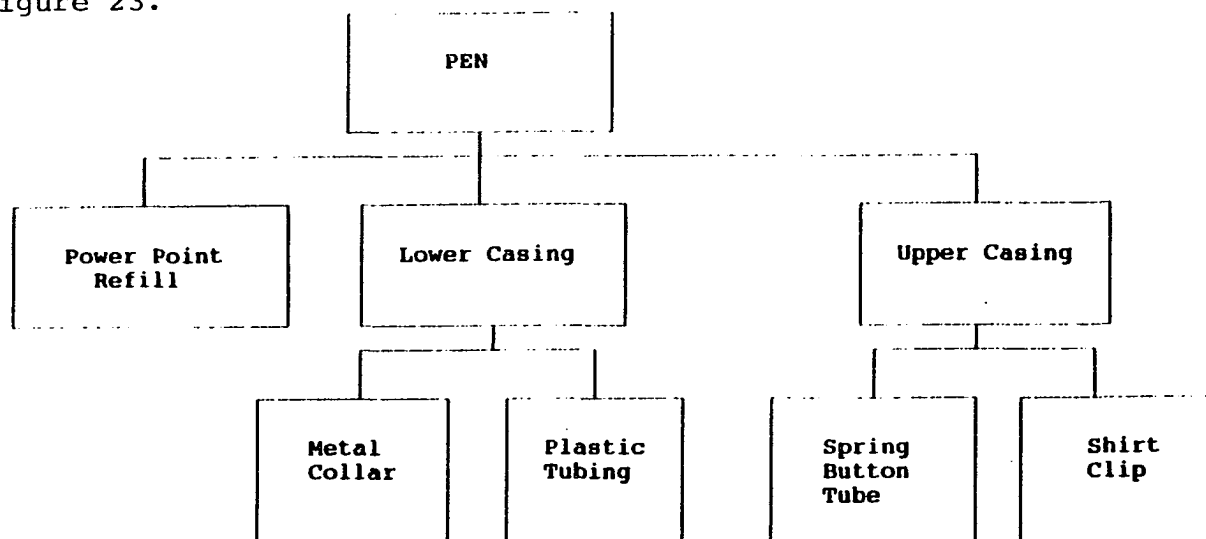
Figure 22.



Item #	Description	Relative Level	Lead Time	Quantity Per
000.10	Starship, Model 1	0	1 week	
004.10	Wing, Short Yellow	1	1 week	2
009.22	Wing, Short Blank	2	1 week	1
002.10	Folded Parallelogram	1	1 week	1
009.21	Parallelogram Blank	1	1 week	1
009.04	MRP Game Label	1	2 weeks	1
009.01	Label: Model 1	1	2 weeks	1
001.10	Blue Disk/Motor Ass'y	1	1 week	1
003.10	Blue Disk	2	1 week	1
003.60	Motor, Non-Remov	2	3 weeks	2
009.05	Staples	1	1 week	2

Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8

Figure 23.



Item #	Description	Relative Level	Lead Time	Quantity Per
8529	Pen	0	1 day	
8503	Power Point Refill	1	5 days	1
8504	Lower Casing	1	1 day	1
7920	Plastic Tubing	2	2 days	1
7930	Metal Collar	2	1 day	1
8505	Upper Casing	1	1 day	1
7935	Spring Button Tube	2	2 days	1
6849	Shirt Clip	2	3 days	1

Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9

The three different conditions afforded us the opportunity compare scheduling performances on abstract versus concrete items or familiar versus unfamiliar items. A Latin Square order was used to assign the sequence of the tasks to trainees, as to avoid order effects.

Scheduling solutions were scored on a scale of one to five, the lowest for production and the highest for MRP/production coordinated solutions. Examples of production, MRP and coordinated solutions for the "A" item are displayed in Figures 24, 25 and 26.

Figure 24. A Typical Production Schedule

Schedule 200 A to be delivered in August:

Item	Description	Lead Time	Level	Quantity Per
A	A	2 mo.	0	0
B	B	1 mo.	1	1
C	C	1 mo.	1	1
D	D	2 mo.	2	1

	JAN	FEB	MA	APR	MAY	JUN	JUL	AU	SEP	OCT	NO	DEC
					50 A	50 A	50 A	50 A				
	25 B	25 B	25 B	25 B	25 B	25 B	25 B	25 B				
	25 C	25 C	25 C	25 C	25 C	25 C	25 C	25 C				
	75 D	75 D	75 D	75 D	50 D	50 D						

Figure 25. An MRP Schedule

Schedule 200 A to be delivered in August:

Item	Description	Lead Time	Level	Quantity Per
A	A	2 mo.	0	0
B	B	1 mo.	1	1
C	C	1 mo.	1	1
D	D	2 mo.	2	1

	JAN	FEB	MA	APR	MAY	JUN	JUL	AU	SEP	OCT	NO	DEC
A						200						
B					200							
C					200							
D			200									

Figure 26. An MRP and Production Coordinated Schedule

Schedule 200 A to be delivered in August:

Item	Description	Lead Time	Level	Quantity Per
A	A	2 mo.	0	0
B	B	1 mo.	1	1
C	C	1 mo.	1	1
D	D	2 mo.	2	1

	JAN	FEB	MA	APR	MAY	JUN	JUL	AU	SEP	OCT	NO	DEC
A			50	50	50	50						
B		50	50	50	50							
C		50	50	50	50							
D		100	100									

Trainees who adopted a production strategy usually scheduled items from the earliest time possible, moving forward on the calendar to the due date, and spreading quantities of items out across time. MRP solutions are derived by time phasing the items in lot for lot quantities from the due date back and from the top down in item structure. In other words, if 200 "A" are due in August, and the lead time for "A" is 2 months, 200 "A" would be marked for June. A coordinated strategy would consider the formal MRP scheduling strategy in the context of the "real world," making allowances for issues such as capacity or vendor reliability. Transitional scheduling solutions resulted when trainees attempted to approach the problem with an MRP strategy by ordering in lot for lot quantities or starting the schedule from the due date back; however, in order to produce a "time-phased" MRP schedule, backward scheduling, item structure and lot for lot quantity must be coordinated.

Pre- and post-training card sorting and scheduling conditions are summarized in Table 2, with target MRP and production concepts.

Table 2.

Pre- and Post-Training Probes and Target Concepts

Probe	Pre-Training	Post-Training 1	Post-Training 2	Post-Training 3
Card Sorting	Intek	Intek	Ship	
Scheduling	A	A	Ship	Pen

Probe	MRP Concepts	Production Concepts
Card Sorting	Top Down Item Structure Redundancy	Bottom-Up Processing Transformation
Scheduling	Item Structure Lot for Lot Quantity Just In Time Time Phasing	Bottom-Up Processing Capacity Just In Case Forward Scheduling

CHAPTER 3.

ANALYSES

Non-Verbal Performance Analysis. Non-verbal performance on card sorting was scored on a scale of one to four and scheduling tasks were scored on a scale of one to five, with the lowest scores reflecting the production perspective and the highest scores reflecting an MRP and production coordinated perspective in executing these tasks.

Card Sorting. Trainee's card sorts were copied during the interviews. Production sorts received a score of one. Card sorts that reflected an attempt to make use of "level" or "used in" information but that did not result in an MRP item structure received a score of two. MRP sorts received a score of three, and MRP/production coordinated sorts received a score of four. (See Figures 15, 16, and 17 for illustrations of the different solution strategies).

Scheduling. Schedules written by trainees were analyzed and scored in a similar way. If on the calendar, the trainee had used a production strategy, the scheduling score received was one. This was reflected in schedules that had distributions of quantities across the year, a starting date in January and a general disregard for the item structure constraints. Some trainees approached the scheduling task with a global MRP strategy, but failed to operationalize any specific MRP concept. For example, the backward scheduling concept was applied broadly to level one and level two, but lead times for individual items were neglected. Those trainees who successfully operationalized backward scheduling, but failed to integrate item structure received a non-verbal performance score of three in the scheduling tasks. Trainees who

integrated and operationalized backward scheduling and item structure for a time-phased schedule received a score of four. Finally, those few trainees who coordinated time phasing with production experience, taking into consideration issues of capacity or unreliable vendors, received a score of five. Figures 24, 25 and 26 illustrate production, MRP and coordinated scheduling solutions.

Discourse Analyses. All interviews were audio-cassette recorded, and portions of the tape surrounding the scheduling and card sorting tasks were transcribed. Transcripts were coded for 1) MRP and production terms; 2) MRP, production and coordinated concepts expressed in propositions; 3) discourse structure in the form of modal operators; and 4) over-arching verbal performance scores.

Terms. Since it was hypothesized that terms lead conceptual development, an analysis of MRP and production terminology in pre- and post-training discourse was designed. Table 3 contains a list of the MRP and production term categories relevant to card sorting and scheduling, tracked in pre- and post-training interviews. Trainees' transcripts were coded for presence or absence of these terms in pre- and post-training interviews. The production terms fall into two categories, "Transformation" and "Resource Management." Transformation category encompassing terms surrounding the physical activities that lead to the production, repair or maintenance of items, and the workplace specific nomenclature assigned to these items. For instance, in our site, "valve" is a common item category for which many varieties exist in the pneumatic

shop. In performing the scheduling task, some trainees assigned abstract "valve" to the "A" item as a way to give concrete content. The words "item" and "part" are also transformation terms, since they refer generally to the objects under transformation. On the other hand, resource management refers to the activities that support transformation, and terms in this category are related to scheduling, purchasing, labor, capacity and other issues of the like. A greater proportion of resource management terms were expected to be generated during the scheduling task than during the card sorting task, simply because card sorting is directly related to transformation issues and can be successfully executed without much consideration for resource management.

While the frequency of production terminology is expected to be proportionally higher in pre-training than post-training tasks, production terms are predicted to be frequent in post-training, as well, simply because MRP cannot replace production. MRP is an abstraction from production, and although MRP can be isolated to a certain extent, most of the production terms listed in Table 3 apply to the MRP domain, as well.

Nonetheless, the MRP domain has an exclusive set of terminology, and the targeted set of MRP terms is presented in Table 3. The item structure category was observed for the card sorting task, entailing terms such as "level," "parent-child relationship," "bill of material," and so on. Time phasing applied to the scheduling task, and terminology in this category included "backward scheduling," "horizon," and so on. There are specific MRP terms that are actually presented on the cards in the card

sorting task, "level," and on the pages of the scheduling questions, "level" and "lead time," that are tracked in this analysis. The exposure of these specific terms to all trainees in pre-training interviews afforded an opportunity to analyze their use before and after training. These terms were coded for presence and sub-coded as "stated" or "used correctly." The logic behind this further qualification was that if the terms presented in pre-training materials were stated but not used correctly, a shift to "used correctly" in post-training interviews could be observed and used to support the hypothesis that terms lead concept development.

Table 3.

MRP and Production Terms	
MRP	Production
Item Structure Terms	Transformation Terms
Level	Item
End Item	Part
Parent-Child Relationship	Make
Family Tree	Assembly
	Finished Good
Quantity Terms	Component
	Material
Lot for Lot	Repair
Net Available	"Valve"
Projected On Hand	"Gasket"
Gross-to-Net Logic	
Time Phasing Terms	Resource Management Terms
Purchase Lead Time	On Hand
Manufacturing Lead Time	Labor
Time Fence	Capacity
Horizon	Schedule
Backward Scheduling	Work/Purchase Order
	Lead Time

Propositions. Interview transcripts were segmented into minimal subject/predicate propositions. Following the internalization hypothesis, if MRP concepts are being isolated and internalized, the need to talk aloud through problem-solving should decrease with development. While some trainees would enter the pre-training interviews with little or no MRP knowledge, other would enter at more advanced stages. Therefore, the mean number of relevant propositions was expected to decrease in post-training card sorting and scheduling tasks.

The overall decrease in mean number of propositions with conceptual development should also be characterized by a shift in proportions of propositions related to production and MRP categories. A decrease in production propositions will be followed by a rise in MRP propositions to ultimate balance between MRP and production with coordinated propositions emerging.

Discourse Content and Structure.

Discourse Analysis: Content

Propositions were coded for content into one of four categories: 1) "Given" 2) Production 3) MRP 4) MRP/Production Coordinated. In the card sorting tasks, the Given category is for propositions relating to information on the card, such as the part numbers and descriptions at the top, as well as the "level" and "used in" information typed at the bottom. Propositions assigned to the Production category are related to

the transformation of material into the finished good. MRP coded propositions are restricted to item structure concepts clearly expressed in the process of sorting the cards or explaining solutions. Finally, MRP and Production Coordinated propositions are those in which the constraints or demands of production are considered simultaneously with item structure.

In the scheduling tasks, propositions were assigned to the Given category when the trainees referred to the information on any part of the scheduling question sheets, such as lead times, the given item structure, quantity information, or questions and comments about the calendar and due dates. Propositions related to the Production category when trainees considered capacity, spreading the work and purchase orders out across the calendar or when trainees constructed forward schedules. Propositions in the MRP category were assigned to three sub-concepts: Lot for Lot Sizing, Backward Scheduling and Time Phasing. Lot for Lot Sizing of quantities refers to the strategy of ordering the entire lot of a particular order for an end item, as opposed to spreading the whole quantity out across several intervals. Backward Scheduling refers to the strategy that launches a schedule from the future due date back toward the present, but does not necessarily integrate item structure for time phasing. Time phasing refers to the integration of backward scheduling and item structure in such a way that the higher level assemblies are never scheduled before the lower levels.

MRP and Production Coordinated propositions were coded as such if the propositions reflected attempts to compare MRP with production in scheduling

strategies, to explain the functional relationship between the "real world" and the ideal MRP world, or to represent the perspective of one system upon the other.

The method for segmenting and coding interview transcripts for MRP, production and MRP and production coordinated concepts had been developed in previous research (Zazanis, 1992). Inter-rater reliability was tested and agreement of 86% was achieved.

See Tables 4a and 4b for examples of propositions in each category for card sorting and scheduling tasks.

Table 4a.

Examples of Streams of Propositions on Card Sorting

Each of the following examples was excerpted from a transcript:

Givens

(1) ...and this is what GTN /
 whatever number does /
 it is relative level whatever /
 CTN I don't know /

Production

(2) ...okay so you more or less would paint it /
 almost when you're when you're through with it /
 * I think /
 this is a this is a tack board first/
 then you get the size /
 then you got it cut /
 you gotta have it built /
 this...these four here will be paint thinners/
 that you use to mix with the paint to be paint /
 first you put the thinners in the paint /

Item Structure

(3) well there was a finished product/
 and I have all the level ones/
 then I have the subassemblies of the level ones/
 which are the level twos/

MRP and Production Coordinated

(4) ...the labels so for ordering for a system I guess /
 * that would be correct /
 but the order of which you'd have to do it physically /
 they [the process and the MRP system] would not go together /

* These propositions were not assigned codes from the categories under which they are listed, but they are present in streams of propositions surrounding the MRP, production and coordinated concepts.

Table 4b.

Examples of Streams of Propositions on Scheduling

Givens

(1) ...now it's [the information table] telling me /
that it takes /
the lead time is two months /

Production

(2)...if there was a problem um if there was a problem /
you'd wanna know about it as soon as possible /
so by doing a fraction of it in January /
you would know you would know early up /
you could order the entire quantities in January as opposed to a fraction of it /

Lot for Lot Quantity

(3)...400 of the uh 00410 which is the wing short yellow /
cause quantity per is two /
200 of 00210 which is the um folded parallelogram /

Backward Scheduling

(4)...so I would schedule B at the same time as A/
A: no I could schedule that a month later okay/

Time Phasing

(5)...so item B if I wanna have it ready by June /
I gotta order it in May /
so um I will order 200 200 B's in May /
so they'll be there in June /
I would order 200 C's also in May /
cause there's one month lead time /
and there's one per A /

MRP/Production Coordinated

(6)...I wanna have the parts with enough time for me to just make em without getting all the parts /
until day 8 and then have to make em all in one day /
because if you rely on that /
and there's a mishap /
uh something's put together wrong /
or something breaks something like that /
as long as I have my parts have my parts before day 8 /

Discourse Analysis: Structure

According to Tannen (1979), the structure of an utterance can reflect deep underlying knowledge implicit in discourse. The following discourse markers signal richness in conceptual repertoire:

Connectives:

Temporal (then, when)

Conditional (if, maybe)

Causal (because, so)

Disjunctive (but, or, unless)

Modal Operators:

Generalization, or the general "you", as in "When you buy material, you write out a purchase order..."

Modals, or "would" "could" "should" as in "I would use silver plating for that item..."

Hedges, or words that reflect a range of possibilities or a larger category, as in "There are certain items you don't order until you know they're broken....," as "certain" reflects that the speaker knows several item scenarios.

Transcripts from interviews with MRP experts revealed high concentrations of these discourse markers surrounding MRP and production coordinated propositions, illustrated in the following excerpt:

Interviewer: Let me put it another way...there are some people who think that if all the information is perfect in the [MRP] system then you don't need any human intervention or monitoring.

Interviewee:
there's only a certain (**hedge**) amount of capacity/
...MRP systems are...inherently (**hedge**) capacity dumb/

It'll [MRP] say /
you (**generalization**) need 8 million man hours this week or
(**disjunctive connective**) people (**hedge**) hours/

and next week you (**generalization**) need 3 people hours/
The week after (**temporal connective**) you (**generalization**) need 6/

And it [MRP] will assume /
that you (**generalization**) have 8 million people (**hedge**) hours worth
of stuff this week /

and then (**temporal connective**) you're (**generalization**) going to lay
off all those people next week and only (**hedge**) work 3 hours/

so (**causal connective**) MRP systems are not, at least currently (**hedge**)
not, capacity sensitive/

that's a major (**hedge**) thing /

I'm looking for intelligent (**hedge**) systems/

that would (**modal**) take into account this capacity requirement/

now (**temporal connective**) where the human (**hedge**) intervention
comes in is in deciding/

The expectation from the analysis conducted on the present data was to find a high concentration of discourse markers surrounding production propositions, as this is the domain of trainees' expertise at entry point in the training program. Proportions of discourse markers surrounding beginning MRP concepts produced by some trainees in pre-training interviews are expected to be significantly lower than the discourse

marker proportions surrounding production propositions. After training, for those trainees who generate MRP propositions, the proportions of discourse markers are expected to rise significantly from pre-training proportions. For MRP concepts that are fully developed, mean differences between discourse marker proportions surrounding MRP and production propositions are expected to be insignificant.

Verbal Performance Scores.

Because the process of conceptual development is complex, as hypothesized here, un-integrated comparisons between term analysis results, proposition analysis results, and discourse marker analysis results with mean non-verbal performance scores rendered an inadequate examination of the relationship between trainees' speech and non-verbal performance in interviews. Therefore, overall verbal scores were assigned to each trainee, based on all verbal measures (terms, and proposition structure and content). On par with non-verbal performance scores for card sorting and scheduling, verbal scores ranged from one to four for card sorting and from one to five for scheduling. Recall that scales for non-verbal performance scoring were oriented with production at the lowest end and MRP and production coordinated at the highest. Verbal scores were structured the same way.

The charts below present the scheme for assigning verbal performance scores.

Verbal Performance Scoring Charts for Card Sorting and Scheduling

Card Sorting:	Level			
	1	2	3	4
Production Terms and Propositions	X			
MRP Terms		X		
Propositions: MRP Item Structure Discourse Markers			X	
MRP/Production Coordinated Discourse Markers				X

Scheduling:	Level				
	1	2	3	4	5
Production Terms and Propositions	X				
MRP Terms		X			
Propositions: MRP Lot for Lot		X			
MRP Backward Scheduling				X	
MRP Time Phasing Discourse Markers				X	
MRP/Production Coordinated Discourse Markers					X

A verbal score of one reflected no MRP terms or propositions in discourse. In card sorting, a score of two was assigned to trainees who used MRP terms but did not present item structure propositions. A verbal score of three was granted to the card sorting verbal performance if item structure propositions were present and associated with discourse markers; verbal scores of four were only assigned to card sorting verbal performance in which MRP and production coordinated propositions were present.

In scheduling discourse, again, a verbal score of one reflected no MRP terms or propositions. Verbal scores of two were given to trainees who employed MRP terms. A verbal score of three was assigned to trainees who fully expressed MRP concepts of backward scheduling in propositions but who did not integrate item structure for time phasing. Fully expressed, integrated concepts of time phasing qualified for a score of four, and MRP and coordinated propositions were the criteria for scores of five.

Verbal and non-verbal performance could thus be analyzed and compared for hypothesis testing. If verbal scores were significantly higher than non-verbal scores, support would be gained for the mediational value of semiotic systems. If verbal scores were inconsistently higher and lower or significantly lower than non-verbal scores, the relationship hypothesized in this dissertation would have to be reconsidered.

CHAPTER 4.

RESULTS

The results are presented in three sections. The first section focuses on trainees' verbal and non-verbal performance before and after training on card sorting and scheduling tasks; this section relates to the hypothesis that language leads thought in conceptual development. The second section focuses on the relationship between independent variables (job title, age, educational history, use of and training on previously existing inventory control technologies and participation in a comprehensive 18-month TA training program) and verbal/non-verbal performance on card sorting and scheduling tasks. Finally, the third section will present three individual cases of pre- and post-training results to illustrate qualitatively the microgenetic process hypothesized to characterize adult conceptual development.

Section I. Pre- and Post-Training Verbal and Non-Verbal Performance

Interview transcripts were analyzed for MRP and Production term use, propositions characterized by MRP, Production or Coordinated perspectives, and discourse markers surrounding those propositions, reflective of cognitive support for their content. (See Methods for details). This section reports the verbal performance results, as well as the non-verbal performance scores, based on scheduling worksheets and card sort notations taken immediately after the task. Finally, the non-verbal and verbal performance results are compared.

Terms. Terms are expected here to lead concept development. Furthermore, in conjunction with the internalization hypothesis, term use is expected to decrease, once the underlying concept has been acquired. Therefore, the pattern proposed for term use in conceptual development is: 1) initial use of terms without full concept comprehension and operations; 2) the use of terms to scaffold concepts and operations; 3) finally, the use of terms to explain or externalize the concepts that had been operationalized. The percentages of trainees using production and MRP terms during pre- and post-training card sorting are presented in Table 5. Recall that "Intek" stands for the unfamiliar item representing the finished good from a hardware factory, and the "Ship" stands for the starship used in the training workshop. (See Table 2 for an outline of the card sorting conditions and Table 3 for a list of target production and MRP terms).

Table 5.

Percentage of Trainees Using Production and MRP Terms
During Pre- and Post-Training Card Sorts

	Pre-Training Intek (N=30)	Post-Training Intek (N=29)	Post-Training Ship (N=27)
<u>Production Terms</u>			
Transformation	89.7	92.9	81.5
Resource Management	27.6	25.0	25.9
<u>MRP Terms</u>			
"Level"			
Stated	72.4	32.1**	3.7**
Used Correctly	48.3	71.4**	66.7**
Item Structure	51.7	35.7*	33.3*
** p < .001			
* p < .05			

"Level" is a term that was written on each card; the production terms and "item structure" category of terms were generated independently by trainees. (See Table 3 for a list of terms in each of the production and MRP categories). There were no significant shifts in production terms from pre- to post-training. Time (2) X Term (2) Anovas were performed on use of the MRP term "level" (stated, used correctly) with

repeated measures on time for pre- to post-training Intek and Ship conditions. These analyses revealed no main effects, but there were Time by Term Use interactions in both the Intek ($p < .001$, $F=22.44$, 28,1), and Ship ($p < .001$, $F=51.22$, 28,1) conditions. (See Table 5). This result lends support to the hypothesis that concept development begins with term use and that terms are, in fact, used in the process of conceptual development. T-tests revealed that the percentage of trainees using item structure terms decreased significantly after training, for card sorting on both the Intek item ($t=2.26$) and the Ship ($t=2.11$). Following the internalization hypothesis, once a concept has fully developed, term usage may not be necessary to operationalize the concept. This is reflected by the result on "item structure" term use.

Table 6 presents the percentages of trainees on scheduling tasks who 1) used production terms, 2) stated versus used correctly "level" and "lead time," which appeared on the worksheets (see Figure 21), and 3) used "time phasing" terms. No significant differences in percentages of trainees using production terms resulted from pre- and post-training analyses. Yet, significant shifts from "stated" to "used correctly" for "level" and "lead time" were revealed. Time (2) X Term (2) Anovas were performed on use of the MRP term "level" (stated, used correctly) with repeated measures on time for pre- to post-training scheduling A, Ship and Pen conditions. These analyses revealed no main effects, but there were Time by Term Use interactions for all three post-training conditions, scheduling A ($F=10.67$, 29,1) $p < .003$), scheduling Ship ($F=38.26$, 29,1) $p < .001$), and scheduling Pen ($F=38.26$, 29,1) $p < .001$). (See Table 6).

Time (2) X Term (2) Anovas were also performed on use of the MRP term "lead time" (stated, used correctly) with repeated measures on time for pre- to post-training scheduling A, Ship and Pen conditions. Again there were no main effects, but the Time by Term Use interactions were reliable for all three post-training conditions, scheduling A ($F=3.5, 29,1$) $p < .070$), scheduling Ship ($F=6.57, 29,1$) $p < .016$), and scheduling Pen ($F=5.52, 29,1$) $p < .026$). (See Table 6).

Thus, the analysis of pre- and post-training term use on scheduling tasks resulted in similar findings to card sorting tasks; however, t-tests showed that the use of "time phasing" terms actually increased in post-training Ship scheduling ($t=-1.98$) and Pen scheduling ($t=-1.99$), also displayed in Table 6.

Table 6.

Percentage of Trainees Using Production and MRP Terms
During Pre- and Post-Training Scheduling

	Pre-Training A (N=30)	Post-Training A (N=28)	Post-Training Ship (N=29)	Post-Training Pen (N=27)
<u>Production Terms</u>				
Transformation	96.7	80.0	93.1	88.0
Resource Management	86.7	80.0	86.2	76.0
<u>MRP Terms</u>				
"Level"				
Stated	36.7	13.3*	0.0**	8.0**
Used Correctly	3.3	16.7*	48.3**	32.0**
"Lead Time"				
Stated	40.0	6.7+	13.8++	8.0++
Used Correctly	43.3	46.7+	58.6++	52.0++
Time Phasing	23.3	26.7	41.4++	48.0++
+ p < .1 ++ p < .05 * p < .01 ** p < .001				

Further into this results section, it will become evident that overall measures on both verbal and non-verbal performance yield higher achievement results on the card sorting tasks. The card sorting task requires only the concept of item structure, while the scheduling task requires not only the concepts of item structure, lot for lot quantity and backward scheduling, but the integration of the three for the performance to be scored as a complete MRP solution. Since the average performance of trainees on scheduling reflected a transitional stage (while card sorting performances reflected acquisition), as hypothesized, term usage was on the increase for scheduling but decreasing for card sorting. Finally, production terms were used prevalently in both card sorting and scheduling tasks. As MRP is an abstraction from production, no solution could be properly explained without using basic production terms, such as "item," "part," "make," "goes into," "schedule," and so on.

Propositions. If conceptual development proceeds from semiotic mediation to internalization, resulting in the ultimate ability to operationalize a given conceptual system, as hypothesized, one would expect a general decrease in discourse surrounding problem solving to result with increasing comprehension. Thus, as the mediated terms and concepts are internalized, the need to talk aloud through problem-solving activities was predicted to decrease (much in the way Vygotsky characterized the internalization of speech in child development). Table 7 contains the mean number of relevant propositions uttered during the course of pre- and post-training card sorting. Here, t-tests show highly significant decreases between the pre-

training mean of 30.97 and the post-training Intek mean of 18.73 ($t=3.14$, $p < .004$) and the post-training ship mean of 16.7 ($t= 3.68$, $p < .001$).

Table 7.

Mean Number of Relevant Propositions During Pre- and Post-Training Card Sorts

	Pre-Training	Post-Training	Post-Training
	Intek (N=30) Mean	Intek (N=29) Mean	Ship (N=27) Mean
Propositions	30.97	18.7*	16.7**

* $p < .01$

** $p < .001$

Displayed in Table 8, less significant decreases in mean number of post-training propositions occurred for the scheduling tasks. This can be explained by the fact that the average trainee was in a transitional stage of conceptual development, and scaffolding the task with verbalization characterizes the interviews. Note that the only significant decrease ($t=4.27$, $p < .001$) from pre- to post-training propositions (pre-training = 40.43; post-training A = 21.43), occurred on the task involving the abstract, "A" object, which was a) familiar, as it had been presented in the pre-training task, and b) indisputably simpler, as it contained only three subcomponents, while the ship and the pen had over ten (see figures 21, 22 and 23).

Table 8.

Mean Number of Relevant Propositions
During Pre- and Post-Training Scheduling Tasks

	Pre-Training A (N=30) Mean	Post-Training A (N=28) Mean	Ship (N=29) Mean	Pen (N=27) Mean
Propositions	40.4	21.4*	33.6	29.0

$p < .01$

Proportions of Propositions Related to Production and MRP. It was hypothesized that trainees would initially attempt to map the MRP system onto their existing production knowledge. When discrepancies and counter-intuitive concepts are encountered between MRP and Production, the systems would be isolated. Once the MRP concepts have been internalized and integrated, the two systems could be coordinated.

Transcripts of discourse surrounding the card sorting and scheduling tasks were segmented into propositions. Those propositions relevant to card sorting were assigned to one of four categories: 1) Given - presented in the interview materials or communicated by the interviewer; 2) Production - all talk related to traditional production and planning; 3) item structure - the MRP top-down, parent-child representation of an end item; 4) MRP/Production coordinated - the integration of abstract MRP item structure concepts with manufacturing in the "real world." The proportions among all relevant propositions related to these four categories are presented in Table 9.

Table 9.

Average Proportions of Pre- and Post-Training Propositions During Card Sorting
Related to Production, Item Structure and Coordinated MRP and Production

	Pre-Training	Post-Training	Post-Training
	Intek (N=30) Mean	Intek (N=29) Mean	Ship (N=27) Mean
Givens	.68	.54*	.46*
Production	.23	.24	.24
Item Structure	.09	.18*	.20*
Coordinated	.01	.04+	.10*

* $p < .01$

+ $p < .10$

Results here show that in pre-training interviews, the highest proportion of propositions, .68, was related to the "givens," followed by production propositions, .23, which more than doubled the proportion of propositions related to item structure, .09. The proportion of MRP and production coordinated propositions equaled only one percent of all relevant propositions. In post-training interviews, there was no significant increase or decrease in proportion of propositions related to production (Intek = .24; Ship = .24), while propositions related to "givens" decreased significantly on post-training Intek ($t = 3.16$, $p < .004$) and Ship ($t = 3.02$, $p < .006$) conditions. Conversely, proportions of propositions related to item structure doubled from .09 in the pre-training condition to .18 in the Intek condition ($t = 2.74$, $p < .01$) and .20 in the Ship condition ($t = 2.72$, $p < .01$). Finally, while increases coordinated propositions showed a non-significant trend (from .01 to .04) for the Intek condition ($t = 1.72$, $p < .097$), the increase in the Ship condition to .10 was significant ($t = 2.82$, $p < .009$). In pre-training interviews, however, production only comprised 23 percent of all relevant talk and remained proportionally similar throughout post-training conditions.

The results yielded by analyses of propositions from scheduling tasks confirms a microgenetic trajectory of isolation of the new conceptual system, followed by internalization. Table 10 displays proportions of propositions related to "givens," production, various MRP scheduling concepts (Lot for Lot Quantity, Backward Scheduling, and Time Phasing), and MRP/production coordination in pre- and post-training conditions.

Table 10.

Average Proportions of Pre- and Post-Training Propositions During Scheduling
Related to Production, Lot for Lot Quantity, Backward Scheduling,
Time Phasing, and Coordinated MRP and Production

	Pre-Training	Post-Training	Post-Training	Post-Training
	A (N=30) Mean	A (N=28) Mean	Ship (N=29) Mean	Pen (N=27) Mean
Givens	.53	.54	.57	.57
Production	.40	.21**	.24*	.25*
Lot for Lot Quantity	.01	.07+	.07*	.04++
Backward Scheduling	.03	.07	.03	.19
Time Phasing	.02	.09++	.07++	.07++
Coordinated	.002	.01	.01++	.01

+ $p < .10$ ++ $p < .05$ * $p < .01$ ** $p < .001$

Proportions of propositions related to "givens" outnumbered all other topics, across pre- and post-training conditions and showed no significant increases or decreases. In the pre-training condition, the mean proportion of propositions related to production was 40 percent, while the mean proportions in post-training conditions was significantly lower: 21 percent in A scheduling ($t=3.54$, $p < .001$), 24 percent in Ship scheduling ($t=3.38$, $p < .002$) and 25 percent in Pen scheduling ($t=3.01$, $p < .006$). This

decrease reflects the isolation process, not captured in analyses of discourse surrounding card sorting, as a greater percentage of trainees entered the pre-training interview at a more advanced level on item structure concepts than MRP scheduling concepts.

On the whole, there were significant increases in proportions of propositions related to MRP concepts on all post-training conditions surrounding scheduling tasks. Increases in proportions of propositions related to Lot for Lot Quantity and Time Phasing concepts were significant; however, increases in proportions of propositions related to Backward Scheduling were insignificant. From the pre-training proportion of one percent in the Lot for Lot Quantity category, proportions climbed to seven percent in post-training A scheduling ($t=-1.83$, $p < .08$) and Ship scheduling ($t=-3.12$, $p < .004$) and four percent in Pen scheduling ($t=-2.32$, $p < .029$). Time phasing proportions increased from two percent in pre-training to nine percent in A scheduling ($t= -.74$, $p < .032$), seven percent in Ship scheduling ($t=-2.35$, $p < .026$), and seven percent in Pen scheduling ($t= -2.71$, $p < .012$). Furthermore, the only significant increase in propositions related to MRP and Production Coordinated concepts occurred on the Ship scheduling task, and while the increase was significant ($t=2.16$, $p < .039$), the mean proportion of propositions in this category for the Ship scheduling task was only one percent. Overall, the significant decrease in mean proportions of production propositions and increase in MRP propositions reflect an earlier stage in the microgenetic process of MRP scheduling concept development, as compared with results on Item Structure concept development, which were associated with higher

increases in propositions related to both item structure and MRP/production coordination.

Discourse Markers Related to Production and MRP. A major hypothesis in this dissertation is that discourse content reflects the mediational role of language and discourse structure reflects conceptual achievement. As the MRP conceptual system is isolated and internalized, a decrease in production talk and increase in MRP talk and ultimate coordination of MRP and production was expected and evidenced in the data summarized above. The analyses of discourse markers surrounding propositions addresses the discourse structure hypothesis. Since production is the domain of expertise that trainees brought with them to the training program, a high proportion of discourse markers surrounding production propositions was expected, while discourse markers were not predicted to be found in the same proportion surrounding concepts in early stages of development. As conceptualization of MRP developed, MRP propositions were expected to be associated with an increase in proportion of discourse markers after training.

Table 11 presents proportions of discourse markers for propositions related to "givens," production, Item Structure and MRP and production coordination. Proportions of discourse markers found in propositions related to "Givens" were expected to be relatively low, since these propositions were referential to materials given to the trainees by the interviewer; thus the shared references were implicit. The propositions that expressed solutions, however, were expected to be surrounded by

higher proportions of discourse markers when trainees were expressing concepts previously developed or, at least, in later stages of development. As predicted, the highest proportions of discourse markers in pre-training propositions related to production.

Table 11.

Mean Proportions of Discourse Markers Per Propositions
Related to "Givens," Production, Item Structure and Coordinated MRP and Production
Comparing Pre- and Post-Training Card Sorting

	Pre-Training	Post-Training	Post-Training
	Intek (N=30) Mean	Intek (N=29) Mean	Ship (N=27) Mean
Givens	.42	.31	.39
Production	.96	.87	.86
Item Structure	.36	1.02*	.71+
Coordinated	.27	.29	.63+

* $p < .01$

+ $p < .05$

After training discourse markers surrounding item structure concepts increased significantly in both the Intek ($t=3.22$, $p < .003$) and Ship conditions ($t=1.96$, $p < .060$), but increases in discourse markers surrounding MRP/production coordinated propositions were significant only on the Ship card sorting task ($t=1.96$, $p < .05$). This

is clearly explained by the fact that the ship was the item used in training; therefore, trainees had the opportunity to coordinate the formal item structure concepts with real production activities. For the Intek item, an unfamiliar finished good, constructing the item structure concept in the context of actual production processes imposed a greater conceptual demand, thus the insignificant increase in discourse markers surrounding these propositions.

Table 12 displays a comparison between proportions of discourse markers surrounding production propositions with all other relevant proposition categories. In the pre-training card sorting task, the mean proportion of discourse markers, .96, for production propositions was significantly higher than that for the categories of "givens," .42 ($t=-3.59$, $p < .001$), item structure, .35 ($t=3.36$, $p < .002$), and coordinated, .27 ($t=4.06$, $p < .001$). In post-training Intek condition, however, there was no significant difference between the mean proportion of discourse markers surrounding production propositions, .87, and item structure propositions, 1.02. Furthermore, in the Ship condition, differences in discourse marker proportions between production, .86, and both item structure, .74, and MRP/production coordination, .58, were insignificant.

Table 12.

Mean Proportion of Discourse Markers Per **Production** Propositions
Compared with "Givens," Item Structure, and Coordinated MRP and Production
During Pre- and Post-Training Card Sorting¹

	Pre-Training Intek Mean	Post-Training Intek Mean	Post-Training Ship Mean
Production	.96	.87	.86
"Givens"	.42*	.31*	.38*
Item Structure	.35*	1.02	.74
Coordinated	.27*	.30*	.58

* $p < .01$

Table 13 displays mean proportions of discourse markers surrounding relevant propositions for pre- and post-training scheduling tasks. There were no significant changes in mean proportion of discourse markers surrounding propositions related to "givens" and production from pre- to post-training scheduling. Within the MRP and Coordinated proposition categories, significant increases in discourse markers did occur. Specifically, mean proportions of discourse markers surrounding time phasing concepts increased in all three post-

¹Table 11 presents comparisons of means between pre- and post-training trials, and missing cases from one trial were excluded from the analysis. Table 12 presents means within pre- and post-training trials, and missing cases were not excluded in the same way. Therefore, means in Tables 11 and 12 are slightly different in certain cells. The same differences will apply to within and between trial comparisons, henceforth.

training conditions, from .16 in pre-training to a proportion of .54 in the A scheduling condition ($t=-2.25$, $p < .03$), .56 in Ship scheduling ($t=-2.68$, $p < .01$), and .67 in Pen scheduling ($t=-3.28$, $p < .003$). Significant increases from pre-training proportion of .06 to post-training A proportion of .39 ($t=-2.63$, $p < .01$) and Ship proportion of .49 ($t=-3.08$, $p < .005$) resulted in the Lot for Lot Quantity category, in the Backward Scheduling category for Pen scheduling from a proportion of .21 in pre-training to .53 in post-training ($t=-2.15$, $p < .04$). Significant increases in mean proportion of discourse markers surrounding MRP/production coordinated propositions resulted in post-training Ship ($t=-2.50$, $p < .018$) and Pen scheduling ($t=-1.38$, $p < .003$); however, as Table 14 reports, these increases did not reach the proportion of discourse markers that was characterized by production propositions.

Table 13

Mean Proportions of Discourse Markers Per Propositions
Related to "Givens," Production, Item Structure and Coordinated MRP and Production
Comparing Pre- and Post-Training Scheduling

	Pre-Training A (N=30) Mean	A (N=28) Mean	Post-Training Ship (N=29) Mean	Pen N(N=27) Mean
Givens	.50	.54	.52	.56
Production	2.05	.67	.68	.79
Lot for Lot Quantity	.06	.39*	.49**	.26
Backward Scheduling	.21	.45	.43	.53*
Time Phasing	.16	.54**	.56**	.67**
Coordinated	.07	.18	.37*	.31**

* $p < .05$

** $p < .01$

Table 14 presents the proportion of discourse markers per production propositions compared with all other proposition categories. In the pre-training scheduling condition, the larger proportion of discourse markers per production propositions tended toward significance for Lot for Lot Quantity ($t=2.05$, $p < .049$), Backward Scheduling ($t=1.84$, $p < .07$), and Time Phasing ($t=1.94$, $p < .06$). Table 14 shows insignificant results from comparisons between discourse markers surrounding post-training production propositions and all post-training MRP

propositions with the one exception of the Lot for Lot Quantity category in the post-training Pen scheduling condition ($t=2.80$, $p < .009$). On the other hand, as stated above, while there were significant increases from pre- to post-training discourse markers in the Coordinated category (see Table 13), these proportions of .18 for the A scheduling coordinated propositions ($t=2.59$, $p < .015$) and .31 for the Pen scheduling coordinated propositions ($t=2.05$, $p < .05$) were significantly lower than those proportions surrounding production propositions. Nonetheless, in the Ship scheduling task, the mean proportion of discourse markers surrounding Coordinated propositions was .37 and for production propositions, .68. Although the mean proportion is clearly lower for this coordinated category than those discourse marker proportions surrounding the post-training production and MRP propositions, this difference is statistically borderline ($t=1.86$, $p < .074$). As with the card sorting task, because the ship was the item used in the training workshop, simulated production experience with the ship lent a context for constructing MRP and production coordinated concepts.

Table 14

Mean Proportion of Discourse Markers Per **Production** Propositions
 Compared with "Givens," Lot for Lot Quantity, Backward Scheduling,
 Time Phasing and Coordinated MRP and Production
 During Pre- and Post-Training Scheduling

	Pre-Training A Mean	A Mean	Post-Training Ship Mean	Pen Mean
Production	1.98	.67	.68	.79
"Givens"	.52	.54	.69	.56
Lot for Lot Quantity	.06++	.39	.49	.26**
Backward Scheduling	.24+	.45	.43	.53
Time Phasing	.47+	.54	.56	.67
Coordinated	.06++	.18++	.37+	.31++
+ $p < .10$ ++ $p < .05$ * $p < .01$ ** $p < .001$				

Verbal and Non-Verbal Performance Scores. In problem-solving activities, the use of MRP concepts in speech was expected to run ahead of the implementation of MRP strategies, or operations. As described in the Methods chapter, a coding scheme was developed to measure both verbal and non-verbal performance, so that a comparison could be made to determine whether or not the use of MRP concepts in speech preceded the implementation of MRP logic to solve the card sorting and scheduling problems. Verbal performance scores were calculated for each trainee based on the use of terms, MRP concepts in propositions and discourse markers surrounding MRP propositions. Non-verbal performances were scored according to the written solutions on scheduling tasks and interviewer notations of completed card sorts during the interviews. Scores ranged from one to four on the card sorting task and one to five for scheduling.

Table 15 presents mean verbal and non-verbal scores for card sorting and scheduling tasks. The mean verbal score for the pre-training card sort was 2.33 and the non-verbal score was 1.97 ($t=-1.88$, $p < .07$). The post-training verbal and non-verbal scores on the Intek sort differed most significantly ($t=-2.70$, $p < .012$), while there was no significant difference between the mean verbal, 3.14, and non-verbal, 2.93, scores on the Ship sort. Differences in mean verbal and non-verbal scores on scheduling tasks were all highly significant. In pre-training scheduling, the mean verbal performance score was 2.1 and the mean non-verbal score was 1.37. Both scores indicate a less advanced entry point in MRP scheduling than card sorting,

and the verbal/non-verbal performance difference is highly significant ($t=-4.43$, $p < .001$). On post-training scheduling for the three tasks, mean scores reached 2.9 on the verbal measure and 2.4 on the non-verbal measure, ($t= -3.44$) for the A task, 3.3 on the verbal and 2.4 on the non-verbal measure ($t=-3.82$) for the Ship task, and 3.3 on the verbal 2.5 on the non-verbal measure ($t=-3.33$), with a significant differences between all verbal and non-verbal means (see table 15). Statistical trends indicate here that at more advanced stages of conceptual development, verbal and non-verbal performance converges, as in the card sorts, whereas, at earlier stages, the concepts advance first in speech and are then operationalized non-verbally, as evidenced by the scheduling scores.

Table 15.

Verbal and Non-Verbal Performance Scores

Card Sorting Tasks				
Performance	Pre-Training	Post-Training		
	Intek (N=30) Mean	Intek (N=29) Mean	Ship (N=29) Mean	
Non-Verbal	1.97	2.66	2.93	
Verbal	2.33+	3.07*	3.14	

Scheduling Tasks				
Performance	Pre-Training	Post-Training		
	A (N=30) Mean	A (N=28) Mean	Ship (N=29) Mean	Pen (N=27) Mean
Non-Verbal	1.37	2.34	2.50	2.48
Verbal	2.10**	2.93**	3.31**	3.27**

+ $p < .07$ * $p < .01$ ** $p < .003$

Section II. Group Differences in Verbal and Non-Verbal Performance Scores

In this section results are presented from the analyses of group differences in verbal and non-verbal performances on card sorting and scheduling. Groups were based on independent variables of job title, age, college educational level, usage of and training on CMS and Talon systems, and participation in the in-house 18-month training program. Verbal and non-verbal scores were based on a scale of one to four in card sorting and one to five in scheduling. Results from previous research (Scribner et al., 1992) suggested that independent variables of education, job title, age, and technological experience and training did not explain differences between individuals' levels of knowledge of and flexibility with MRP and production concepts. These studies were conducted in factories where subjects had already been working with MRP for over five years, and where differences in performance on interview tasks were correlated with access (or lack thereof) to constructive activities with the MRP technology (as opposed to following determined procedures). However, in the present study, the trainees interviewed were developing these MRP concepts. While it was hypothesized that all trainees would learn new MRP concepts through the training workshop, some independent variables may explain differences in the rate and/or pattern of acquisition.

A score of one on both tasks reflects a production strategy; scores of four on card sorting and five on scheduling reflect an MRP and production coordinated perspective. For card sorting, two is a transitional score, and three is the score

given when item structure concepts have been fully operationalized non-verbally, or fully expressed verbally. For scheduling, a score of two represents a transitional solution, while scores of three and four represent progressive stages of time phasing. Non-verbal and verbal scores of three reflect that the trainee has operationalized and fully expressed (respectively) backward scheduling (and usually item structure and lot for lot quantity) without integrating for time phasing. A score of four reflects the full time phasing concept in discourse or operation.

Job Title. Trainees were grouped by title into one of three categories: 1) mechanics, or the air brake maintainers and e-men, who are responsible for physical repair and maintenance; 2) analysts, who construct schedules for repair and maintenance; and 3) managers, whose responsibilities range from supervising mechanics to negotiating budgets for maintenance and repair programs.

Table 16 displays mean verbal and non-verbal performance scores for mechanics, analysts and managers on card sorting in the pre-training interviews. An analysis of variance between group means revealed no significant differences among trainees holding these three titles.

Table 16.

Pre-Training Card Sorting
Verbal and Non-Verbal Performance By Title

Title	Number of Trainees	Non-Verbal Mean Score (Standard Deviation)	Verbal Mean Score (Standard Deviation)
Mechanics	15	1.8 (.94)	2.2 (.86)
Analysts	10	2.3 (.82)	2.5 (1.2)
Managers	5	1.8 (.45)	2.4 (1.1)
Total	30	2.0 (.85)	2.3 (1.0)

Tables 17 and 18 display mean verbal and non-verbal performance scores for post-training Intek and Ship card sorting, respectively. Job title did not emerge as a significant factor in explaining differences in trainees' performance.

Table 17.

Post-Training Card Sorting Intek
Verbal and Non-Verbal Performance By Title

Title	Number of Trainees	Non-Verbal Mean Score (Standard Deviation)	Verbal Mean Score (Standard Deviation)
Mechanics	15	2.5 (.83)	2.9 (.74)
Analysts	9	3.0 (.50)	3.3 (.50)
Managers	5	2.6 (.55)	3.2 (.45)
Total	29	2.7 (.72)	3.1 (.65)

Table 18.

Post-Training Card Sorting Ship
Verbal and Non-Verbal Performance By Title

Title	Number of Trainees	Non-Verbal Mean Score (Standard Deviation)	Verbal Mean Score (Standard Deviation)
Mechanics	15	2.7 (.90)	3.0 (1.0)
Analysts	9	3.2 (.44)	3.2 (.67)
Managers	5	3.2 (.45)	3.4 (.89)
Total	29	2.9 (.75)	3.1 (.88)

Hence, trainees' job experience as analyst, manager or mechanic was not a significant factor in pre- and post-training performance on card sorting. This finding concurs with previous research (Scribner et al., 1991; DiBello and Glick, 1992), where job title did not correlate with MRP and production flexibility. Furthermore, the post-training finding suggests that job title is not a factor in the learnability of the counter-intuitive MRP item structure concept. Analyses of non-verbal performance scores on post-training scheduling tasks, however, produced different results.

Table 19 presents results from analyses of verbal and non-verbal scores among mechanics, analysts and managers on the pre-training scheduling task. There were no significant differences in mean scores between these groups, a finding consistent with the pre-training card-sorting task analysis for these groups.

Table 19.

Pre-Training Scheduling A
Verbal and Non-Verbal Performance By Title

Title	Number of Trainees	Non-Verbal Mean Score (Standard Deviation)	Verbal Mean Score (Standard Deviation)
Mechanics	15	1.2 (.41)	1.8 (1.2)
Analysts	10	1.6 (.97)	2.3 (1.3)
Managers	5	1.4 (.55)	2.6 (1.3)
Total	30	1.4 (.67)	2.1 (1.2)

While the differences were insignificant between mean scores on verbal and non-verbal performances of mechanics, analysts and managers in the post-training A scheduling condition, (see Table 20), job title was a significant factor in post-training Ship and Pen scheduling tasks. Tables 21 and 22 show that analysts' mean score of 3.2 was significantly higher than those of mechanics on both the Ship scheduling ($F=3.87$, $p < .035$) and the Pen scheduling ($F=4.378$, $p < .02$) tasks. (Post hoc Duncan and Student Newman Keuls tests were applied to locate significant differences between group means).

Table 20.

Post-Training Scheduling A
Verbal and Non-Verbal Performance By Title

Title	Number of Trainees	Non-Verbal Mean Score (Standard Deviation)	Verbal Mean Score (Standard Deviation)
Mechanics	14	1.9 (1.2)	2.6 (1.0)
Analysts	10	2.9 (1.2)	3.2 (1.4)
Managers	5	2.4 (.89)	3.4 (1.3)
Total	29	2.3 (1.2)	2.9 (1.2)

Table 21.

Post-Training Scheduling Ship
Verbal and Non-Verbal Performance By Title

Title	Number of Trainees	Non-Verbal Mean Score (Standard Deviation)	Verbal Mean Score (Standard Deviation)
Mechanics	14	2.1 (1.0)	2.9 (1.3)
Analysts	9	3.2* (1.0)	3.7 (1.2)
Managers	5	2.4 (.89)	3.6 (1.7)
Total	28	2.1 (1.1)	3.3 (1.3)

* $p < .036$ ($F=3.78$, $DF=2$)

Table 22.

Post-Training Scheduling Pen
Verbal and Non-Verbal Performance By Title

Title	Number of Trainees	Non-Verbal Mean Score (Standard Deviation)	Verbal Mean Score (Standard Deviation)
Mechanics	12	2.1 (1.0)	3.4 (1.3)
Analysts	10	3.2* (1.0)	3.4 (1.1)
Managers	4	2.0 (.89)	2.5 (.58)
Total	26	2.5 (1.1)	3.3 (1.2)

* $p < .02$ ($F=4.378$, $DF=2$)

The general trend in all three post-training conditions was that analysts reached an average of level three on non-verbal performance measures, reflecting the achievement of operationalizing the backward scheduling strategy; mechanics and managers, improved from pre-training performance, but only to a transitional stage. Relating this finding back to the context of the workplace lends some insight; analysts are in the business of scheduling the remanufacturing activities of the shops. Although mechanics are directly affected by the analysts' schedules in terms of having to meet them, and managers supervise the execution of the schedules or approve the budget to support them, trainees holding mechanic positions do not construct the schedules. Thus, the analysts have experience in constructing schedules to begin with, which works to their advantage in operationalizing new MRP scheduling strategies. In previous research, the factor that significantly distinguished subjects with greater MRP

and production flexibility was opportunity for "constructive activity" on the job. Analysts have a history of constructive scheduling activities, and thus, made a faster transition to operationalizing MRP scheduling strategies than the mechanics and managers.

On the other hand, there were no significant differences in mean verbal scores for these three groups, and mean verbal scores are generally higher in pre-training and all three post-training conditions. The microgenetic trajectory reflected here is that mediation occurred first, and trainees were able to talk through strategies in a more advanced way than was reflected in their non-verbal performance. Thus, the constructive experience facilitated the implementation of the backward scheduling strategy among the analysts; however, as Tables 21 and 22 indicate, all three groups reached this strategy in their discourse surrounding the task, and many trainees, across all three job titles, reached time phasing in discourse.

Age. Table 23 displays the pre-training card sorting verbal and non-verbal means by age groups. No significant differences emerged; however, there is a trend in the data toward lower scores for older trainees, which becomes significant in the post-training Intek card sorting condition, displayed in Table 24.

Table 23.

Pre-Training Card Sorting
Verbal and Non-Verbal Performance By Age

Age	Number of Trainees	Non-Verbal Mean Score (Standard Deviation)	Verbal Mean Score (Standard Deviation)
25-35 Years	10	2.2 (1.0)	2.5 (.85)
36-45 Years	8	2.1 (.83)	2.4 (1.1)
46+ Years	12	1.7 (.65)	2.2 (1.1)
Total	30	2.0 (.85)	2.3 (.99)

Table 24.

Post-Training Card Sorting Intek
Verbal and Non-Verbal Performance By Age

Age	Number of Trainees	Non-Verbal Mean Score (Standard Deviation)	Verbal Mean Score (Standard Deviation)
25-35 Years	9	3.0* (.50)	3.0 (.50)
36-45 Years	8	2.9* (.64)	3.0 (.76)
46+ Years	12	2.3 (.75)	3.2 (.72)
Total	29	2.7 (.72)	3.1 (.65)

* $p < .03$ ($F=4.004$, $DF=2$)

Mean verbal and non-verbal performance scores among the four age groups for post-training Intek and Ship card sorting, are displayed in Tables 24 and 25. Table 24 shows that younger trainees, ranging from 25 to 45 years old, out-perform their older peers, over 45, in the Intek condition, as the differences in mean non-verbal scores are significant ($F=4.004$, $DF=2$, $p < .03$). However, no significant differences resulted from analyses of mean verbal scores or from analyses of verbal and non-verbal performance scores on the Ship condition. Recall that the ship was the item used in the training workshop both in the factory simulation and in the item structure activity; thus, all trainees had the opportunity to physically construct the item structure for the starship in training. As the following results of verbal and non-verbal performances will show, where significant differences between groups on the abstract and/or unfamiliar conditions may occur, it is not as common that these differences hold true on the Ship condition, in which the concrete and familiar item used in training is sorted or scheduled.

Table 25.

Post-Training Card Sorting Ship
Verbal and Non-Verbal Performance By Age

Age	Number of Trainees	Non-Verbal Mean Score (Standard Deviation)	Verbal Mean Score (Standard Deviation)
25-35 Years	9	3.0 (.50)	3.2 (.67)
36-45 Years	8	3.3 (.71)	3.4 (.74)
46+ Years	12	2.7 (.89)	2.9 (1.1)
Total	29	2.9 (.75)	3.1 (.88)

Table 26 contains pre-training mean verbal and non-verbal performance scores on scheduling for the four age groups. The apparently higher scores for the older groups are not significant, but in post-training results, the same trend of higher scores for the younger groups reflected in card sorting results was found from scheduling analyses.

Table 26.

Pre-Training Scheduling A
Verbal and Non-Verbal Performance By Age

Age	Number of Trainees	Non-Verbal Mean Score (Standard Deviation)	Verbal Mean Score (Standard Deviation)
25-35 Years	10	1.1 (.32)	1.7 (1.3)
36-45 Years	8	1.5 (.76)	2.1 (.83)
46+ Years	12	1.5 (.80)	2.4 (1.2)
Total	30	1.4 (.67)	2.1 (1.2)

Tables 27 through 29 show that the mean verbal and non-verbal scores on scheduling A, Ship and Pen tasks are higher among the youngest trainees, aged 25 to 35. In the A scheduling condition the mean non-verbal performance level for the youngest group is 3.1, a significantly higher mean than that of 1.6 for the 36 to 45 year-old group ($F=4.335$, $p < .02$). In the Pen scheduling condition, the 25 to 35 year-olds' mean non-verbal score was significantly higher than that of the oldest group ($F=3.118$, $p < .05$).

Table 27.

Post-Training Scheduling A
Verbal and Non-Verbal Performance By Age

Age	Number of Trainees	Non-Verbal Mean Score (Standard Deviation)	Verbal Mean Score (Standard Deviation)
25-35 Years	9	3.1* (.88)	3.6 (1.0)
36-45 Years	8	1.6 (.92)	2.4 (.92)
46+ Years	11	2.2 (1.3)	2.8 (1.4)
Total	28	2.3 (1.2)	2.9 (1.2)

* $p < .024$ ($F=4.335$, $DF=2$)

Table 28.

Post-Training Scheduling Ship
Verbal and Non-Verbal Performance By Age

Age	Number of Trainees	Non-Verbal Mean Score (Standard Deviation)	Verbal Mean Score (Standard Deviation)
25-35 Years	9	3.1 (.74)	3.7 (1.4)
36-45 Years	8	2.3 (1.0)	2.9 (1.1)
46+ Years	12	2.2 (1.3)	3.3 (1.4)
Total	29	2.5 (1.1)	3.3 (1.3)

Table 29.

Post-Training Scheduling Pen
Verbal and Non-Verbal Performance By Age

Age	Number of Trainees	Non-Verbal Mean Score (Standard Deviation)	Verbal Mean Score (Standard Deviation)
25-35 Years	10	3.1* (.88)	3.8 (1.0)
36-45 Years	7	2.3 (1.0)	2.9 (1.2)
46+ Years	9	2.0 (1.1)	3.0 (1.1)
Total	26	2.5 (1.1)	3.3 (1.2)

* $p < .02$ ($F=4.378$, $DF=2$)

Age was chosen as an independent variable in the original design of the survey because it was suspected that younger trainees might be more motivated to focus on understanding MRP in the training workshop than older trainees whose motives were oriented less toward advancing in the workplace and more toward conserving the status quo or even retiring. As an additional factor, with age comes deep experience with existing concepts and practices which can be counter-intuitive to the MRP conceptual system. Perhaps interference from existing knowledge and practice explains the non-verbal score differentials.

College Education. College degrees are held by trainees from all three job titles and across all age groups. Table 30 presents mean verbal and non-verbal scores on pre-

training card sorting for groups of trainees with varying levels of college education. Significant differences in non-verbal performance ($F=3.302$, $DF=2$, $p < .05$) reflect that the trainees who earned college degrees achieved higher non-verbal performance scores, contrary to expectations based on previous research, which showed no significant positive correlations between educational level and card sorting performance. It appears that operationalizing the "level" and "used in" information on the bottom of the cards was a phenomenon more common to those trainees having taken college courses and significantly more so to those having earned a degree.

Table 30.

Pre-Training Card Sorting
Verbal and Non-Verbal Performance By College Education Level

Level	Number of Trainees	Non-Verbal Mean Score (Standard Deviation)	Verbal Mean Score (Standard Deviation)
No Courses	4	1.5 (.58)	2.3 (1.5)
Some	13	1.7 (.85)	2.2 (.80)
Completed Degree	13	2.4* (.77)	2.5 (1.1)
Total	30	2.0 (.85)	2.3 (.99)

* $p < .05$ ($F=3.302$, $DF=2$)

Furthermore, college experience was a factor in post-training card sorting, as well. While all trainees improved in verbal and non-verbal performance scores, those trainees with a college degree reached a mean non-verbal score of 3.1 on the Intek sorting condition and 3.2 on the Ship sorting condition (see Tables 31 and 32). The difference between trainees with college degrees and those who had only taken some courses or none at all was significant in the Intek condition ($F=5.642$, $DF=2$, $p < .009$). In the Ship condition, trainees who had taken no college courses scored significantly lower than trainees with some college education and/or college degrees ($F=4.67$, $DF=2$, $p < .018$). Hence, a college education appears to be a factor in fully operationalizing the MRP item structure concept.

Table 31.

Post-Training Card Sorting Intek Verbal and Non-Verbal Performance By College Education Level			
Level	Number of Trainees	Non-Verbal Mean Score (Standard Deviation)	Verbal Mean Score (Standard Deviation)
No Courses	4	2.0 (1.2)	3.3 (.96)
Some	13	2.5 (.52)	2.9 (.64)
Completed Degree	12	3.1* (.51)	3.2 (.58)
Total	29	2.7 (.72)	3.1 (.65)

* $p < .009$ ($F=5.642$, $DF=2$)

Table 32.

Post-Training Card Sorting Ship
Verbal and Non-Verbal Performance By College Education Level

Level	Number of Trainees	Non-Verbal Mean Score (Standard Deviation)	Verbal Mean Score (Standard Deviation)
No Courses	4	2.0 (1.2)	2.8 (1.5)
Some	13	3.0* (.58)	3.1 (.86)
Completed Degree	12	3.2* (.58)	3.3 (.65)
Total	29	2.9 (.75)	3.1 (.88)

* $p < .018$ ($F=4.67$ $DF=2$)

Analyses of mean verbal and non-verbal performances in pre- and post-training scheduling tasks result in findings relatively consistent with the card sorting results. Although there are virtually no differences in mean scores on the pre-training task (see Table 33), post-training results support college education as a factor in operationalizing MRP scheduling strategies.

Table 33.

Pre-Training Scheduling A
Verbal and Non-Verbal Performance By College Education Level

Level	Number of Trainees	Non-Verbal Mean Score (Standard Deviation)	Verbal Mean Score (Standard Deviation)
No Courses	5	1.4 (.55)	2.2 (1.1)
Some	12	1.3 (.62)	2.0 (1.1)
Completed Degree	13	1.5 (.78)	2.2 (1.3)
Total	30	1.4 (.67)	2.1 (1.2)

Tables 34 through 36 contain mean verbal and non-verbal scores on post-training scheduling A, Ship and Pen tasks for groups of trainees by college education level. The trend toward college education as a factor in higher non-verbal performance scores is significant for the Ship ($F=5.83$, $DF=2$, $p < .01$) and the Pen ($F=7.876$, $DF=2$, $p < .002$) scheduling tasks. In the Ship scheduling task, trainees holding college degrees achieved significantly higher non-verbal performance scores than the trainees who had never attended any college courses. In the Pen scheduling condition, mean scores for all three groups were significantly different. That is, trainees holding college degrees scored the highest, and trainees with some college credits scored significantly higher than those who had not taken college courses. College education thus emerges as a significant factor in non-verbal performance scores, particularly in cases where the central object of the task is unfamiliar and complex.

Table 34.

Post-Training Scheduling A
Verbal and Non-Verbal Performance By College Education Level

Level	Number of Trainees	Non-Verbal Mean Score (Standard Deviation)	Verbal Mean Score (Standard Deviation)
No Courses	14	1.5 (1.0)	2.5 (1.7)
Some	10	2.2 (1.4)	2.9 (1.2)
Completed Degree	5	2.8 (.92)	3.1 (1.2)
Total	29	2.3 (1.2)	2.9 (1.2)

Table 35.

Post-Training Scheduling Ship
Verbal and Non-Verbal Performance By College Education Level

Level	Number of Trainees	Non-Verbal Mean Score (Standard Deviation)	Verbal Mean Score (Standard Deviation)
No Courses	5	1.4* (.89)	3.2 (1.3)
Some	12	2.3* (1.1)	3.2 (1.5)
Completed Degree	12	3.1* (.86)	3.5 (1.2)
Total	28	2.5 (1.1)	3.3 (1.3)

* $p < .01$ ($F=5.83$ $DF=2$)

Table 36.

**Post-Training Scheduling Pen
Verbal and Non-Verbal Performance By College Education Level**

Level	Number of Trainees	Non-Verbal Mean Score (Standard Deviation)	Verbal Mean Score (Standard Deviation)
No Courses	3	1.0* (.00)	2.7 (1.2)
Some	10	2.2* (.87)	3.3 (1.3)
Completed Degree	13	3.1* (.95)	3.4 (1.0)
Total	26	2.5 (1.1)	3.3 (1.2)

* $p < .002$ ($F=7.876$, $DF=2$)

The microgenetic pattern (mediation to internalization and ultimate integration for operationalizing target concepts) hypothesized in this dissertation receives support from these analyses, as the trend for mean verbal scores to run higher than non-verbal counterparts holds up across groups of trainees by job title, age and educational level. Furthermore, with college level as a significant factor in non-verbal performance, it appears that this type of educational experience expedites the process; however, there is no evidence for structurally different microgenetic patterns across different groups of trainees. For example, there is no group (based on any independent variable, including level of college education) in which mean non-verbal scores are higher than verbal scores. Training on and usage of the pre-existing CMS and Talon technologies are presented next and further confirm this trend.

CMS and Talon Systems. Tables 37 through 39 present mean verbal and non-verbal performance scores on pre- and post-training card sorting tasks among groups based on usage of and training on CMS and Talon systems. These factors had no significance in the pre-training condition, nor in the post-training Ship condition. Yet, in the post-training Intek conditions, mean non-verbal scores were significantly higher for trainees who received training on and/or used these technological systems. The mean non-verbal Intek score for CMS and Talon users was 2.9 and for non-users 2.4, ($F=4.36$, $DF=1$, $p < .046$); the mean non-verbal score for those trained was 3.0 and for the untrained, 2.4 ($F=4.572$, $DF=1$, $p < .041$). Furthermore, the mean verbal performance score on Intek card sorting was significantly higher for trainees who received CMS and Talon training ($F=4.024$, $DF=1$, $p < .04$).

Table 37.

Pre-Training Card Sorting
Verbal and Non-Verbal Performance
By Usage of and Training on CMS and Talon Systems

	Number of Trainees	Non-Verbal Mean Score (Standard Deviation)	Verbal Mean Score (Standard Deviation)
No Usage	16	2.1 (.93)	2.1 (.85)
Usage	14	1.9 (.77)	2.6 (1.1)
Total	30	2.0 (.85)	2.3 (.99)
No Training	19	1.9 (.91)	2.1 (.81)
Training	11	2.0 (.77)	2.7 (1.2)
Total	30	2.0 (.85)	2.3 (.99)

Table 38.

Post-Training Card Sorting Intek
Verbal and Non-Verbal Performance
By Usage of and Training on CMS and Talon Systems

	Number of Trainees	Non-Verbal Mean Score (Standard Deviation)	Verbal Mean Score (Standard Deviation)
No Usage	15	2.4* (.74)	2.9 (.70)
Usage	14	2.9* (.62)	3.2 (.58)
Total	29	2.7 (.72)	3.1 (.65)
* $p < .046$ ($F=4.36$, $DF=1$)			
No Training	18	2.4* (.70)	2.9+ (.68)
Training	11	3.0* (.63)	3.4+ (.50)
Total	29	2.7 (.72)	3.1 (.65)

* $p < .041$ ($F=4.572$, $DF=1$) + $p < .04$ ($F=4.024$, $DF=1$)

Table 39.

Post-Training Card Sorting Ship
Verbal and Non-Verbal Performance
By Usage of and Training on CMS and Talon Systems

	Number of Trainees	Non-Verbal Mean Score (Standard Deviation)	Verbal Mean Score (Standard Deviation)
No Usage	15	2.8 (.94)	2.9 (.88)
Usage	14	3.1 (.47)	3.4 (.84)
Total	29	2.9 (.75)	3.1 (.88)
No Training	18	2.8 (.92)	2.9 (.87)
Training	11	3.1 (.30)	3.5 (.82)
Total	29	2.9 (.75)	3.1 (.88)

Tables 40 through 43 present verbal and non-verbal performance scores on pre- and post-training scheduling tasks among trainees with and without CMS and Talon experience and training. Trends in the data show that trainees with this technological experience and training tend to score higher non-verbally and, in some cases, verbally; however, these differences are not significant with the exception of the pre-training scheduling A condition in which training was a significant factor ($F=5.906$, $DF=1$, $p < .02$).

Table 40.

Pre-Training Scheduling A
Verbal and Non-Verbal Performance
By Usage of and Training on CMS and Talon Systems

	Number of Trainees	Non-Verbal Mean Score (Standard Deviation)	Verbal Mean Score (Standard Deviation)
No Usage	16	1.2 (.40)	1.9 (1.2)
Usage	14	1.6 (.85)	2.3 (1.2)
Total	30	1.4 (.67)	2.1 (1.2)
No Training	19	1.2* (.37)	1.9 (1.1)
Training	11	1.7* (.90)	2.5 (1.2)
Total	30	1.4 (.67)	2.1 (1.2)

* $p < .02$ ($F=5.906$, $DF=1$)

Table 41.

Post-Training Scheduling A
Verbal and Non-Verbal Performance
By Usage of and Training on CMS and Talon Systems

	Number of Trainees	Non-Verbal Mean Score (Standard Deviation)	Verbal Mean Score (Standard Deviation)
No Usage	14	2.2 (1.1)	2.9 (1.1)
Usage	14	2.5 (1.3)	3.0 (1.4)
Total	28	2.3 (1.2)	2.9 (1.2)
No Training	17	2.2 (1.1)	2.9 (1.1)
Training	11	2.5 (1.4)	3.0 (1.5)
Total	28	2.3 (1.2)	2.9 (1.2)

Table 42.

Post-Training Scheduling Ship
Verbal and Non-Verbal Performance
By Usage of and Training on CMS and Talon Systems

	Number of Trainees	Non-Verbal Mean Score (Standard Deviation)	Verbal Mean Score (Standard Deviation)
No Usage	15	2.3 (.87)	3.3 (1.3)
Usage	14	2.7 (1.3)	3.3 (1.3)
Total	29	2.5 (1.1)	3.3 (1.3)
No Training	18	2.4 (.96)	3.2 (1.3)
Training	11	2.7 (1.3)	3.5 (1.4)
Total	29	2.5 (1.1)	3.3 (1.3)

Table 43.

Post-Training Scheduling Pen
Verbal and Non-Verbal Performance
By Usage of and Training on CMS and Talon Systems

	Number of Trainees	Non-Verbal Mean Score (Standard Deviation)	Verbal Mean Score (Standard Deviation)
No Usage	14	2.4 (.99)	3.2 (1.3)
Usage	12	2.6 (1.2)	3.3 (1.1)
Total	26	2.5 (1.1)	3.3 (1.2)
No Training	17	2.4 (1.0)	3.2 (1.2)
Training	9	2.6 (1.2)	3.4 (1.1)
Total	26	2.5 (1.1)	3.3 (1.2)

Generally, usage of and training on the CMS and Talon systems did not distinguish trainees significantly in pre- and post-training card sorting and scheduling tasks, although there were some exceptions, and trends in the data indicate that technological experience plays a role in non-verbal performance. Some trainees may have been able to bridge CMS and Talon experience to MRP, and thus, construct the new MRP concepts at a more advanced level. In other words, just as learning a second language affords greater metalinguistic insight, perhaps some trainees who had CMS and Talon experience were able to compare and contrast the new MRP concepts with their existing technological knowledge and thus advance faster than others.

Participation in the 18-Month Training Program. Only five trainees completed the in-house, 18-Month training program. Contrary to expectation, there were no significant differences between graduates of the program and all other trainees. Tables 44 through 46 contain mean performance scores for these two groups on pre- and post-training card sorting tasks.

Table 44.

Pre-Training Card Sorting
Verbal and Non-Verbal Performance
By Participation in-House 18-Month Training Program

	Number of Trainees	Non-Verbal Mean Score (Standard Deviation)	Verbal Mean Score (Standard Deviation)
No Training	25	1.9 (.79)	2.2 (1.1)
Training	5	2.0 (.97)	2.6 (.73)
Total	30	2.0 (.85)	2.3 (.99)

Table 45.

Post-Training Card Sorting Intek
Verbal and Non-Verbal Performance
By Participation in-House 18-Month Training Program

	Number of Trainees	Non-Verbal Mean Score (Standard Deviation)	Verbal Mean Score (Standard Deviation)
No Training	24	2.5 (.76)	3.2 (.70)
Training	5	2.9 (.60)	2.8 (.41)
Total	29	2.7 (.72)	3.1 (.63)

Table 46.

Post-Training Card Sorting Ship
Verbal and Non-Verbal Performance
By Participation in-House 18-Month Training Program

	Number of Trainees	Non-Verbal Mean Score (Standard Deviation)	Verbal Mean Score (Standard Deviation)
No Training	24	2.9 (.79)	3.1 (.94)
Training	5	3.0 (.71)	3.3 (.71)
Total	29	2.9 (.75)	3.1 (.88)

Tables 47 through 50 contain mean performance scores on pre- and post-training scheduling for participants in the 18-month training program and all other trainees. As was the case in the card sorting tasks, no significant results were yielded from analyses of verbal and non-verbal performance scores by this independent variable for pre- and post-training conditions.

Table 47.

Pre-Training Scheduling A: Verbal and Non-Verbal Performance
By Participation in-House 18-Month Training Program

	Number of Trainees	Non-Verbal Mean Score (Standard Deviation)	Verbal Mean Score (Standard Deviation)
No Training	25	1.3 (.54)	2.0 (1.2)
Training	5	1.8 (1.1)	2.6 (.89)
Total	30	1.4 (.67)	2.1 (1.2)

Table 48.

Post-Training Scheduling A: Verbal and Non-Verbal Performance
By Participation in-House 18-Month Training Program

	Number of Trainees	Non-Verbal Mean Score (Standard Deviation)	Verbal Mean Score (Standard Deviation)
No Training	23	2.4 (1.2)	3.0 (1.2)
Training	5	2.2 (1.0)	2.4 (1.1)
Total	28	2.3 (1.2)	2.9 (1.2)

Table 49.

Post-Training Scheduling Ship: Verbal and Non-Verbal Performance
By Participation in-House 18-Month Training Program

	Number of Trainees	Non-Verbal Mean Score (Standard Deviation)	Verbal Mean Score (Standard Deviation)
No Training	24	2.5 (1.2)	3.3 (1.4)
Training	5	2.4 (.89)	3.2 (1.1)
Total	29	2.5 (1.1)	3.3 (1.3)

Table 50.

Post-Training Scheduling Pen: Verbal and Non-Verbal Performance
By Participation in-House 18-Month Training Program

	Number of Trainees	Non-Verbal Mean Score (Standard Deviation)	Verbal Mean Score (Standard Deviation)
No Training	22	2.5 (1.1)	3.4 (1.2)
Training	4	2.3 (.96)	2.8 (.96)
Total	26	2.5 (1.1)	3.3 (1.2)

Overall, analyses of verbal and non-verbal performance among groups of trainees based on job title, age, college educational level, experience with CMS and Talon systems and participation in the 18-month training program yielded no salient factor to explain why some trainees may have advanced more than others after training or even for pre-training differences. No trainee had any experience working in an MRP environment, and almost all trainees had never heard of MRP before it was introduced into their workplace. The results from these analyses lend more support for the microgenetic pattern hypothesized in this dissertation, as mean verbal scores were higher than mean non-verbal scores for all groups. Furthermore, differences in non-verbal performances appear to reflect a temporary condition in the process. In other words, while some trainees may move faster in conceptual development than others due, perhaps, to certain constructive opportunities, there appears to be no structural difference in development among these groups. This argument is supported by the evidence that 1) for all trainees, regardless of group variables, verbal and non-verbal scores improved after training and 2) that all mean verbal scores were consistently higher than mean non-verbal scores across these group variables.

Section III. Qualitative Results

Three cases of pre- and post-training scheduling solutions presented here exemplify the microgenetic process hypothesized in this dissertation and supported by quantitative results presented in the previous two sections. The microgenetic model emerging from this study has three main phases: 1) term mediation, production and comprehension; 2) concept internalization and isolation; 3) conceptual coordination. Language plays a significant but different role in each of these phases.

In the first phase, language serves as a mediator for new concepts and logic. In other words, terms, such as "level," "lead time," and "item structure" point to new concepts (or old concepts with a new twist). In order to construct the conceptual system, the term meanings must be internalized and integrated. Individuals scaffold themselves through this process by talking (aloud or silently) through problem-solving activities. Individuals may also scaffold new terms and concepts with their existing conceptual systems until there is enough conceptual content in order to isolate the new conceptual system and construct it independently. Individual differences in speech patterns make a significant factor that cannot be overlooked in future studies. A few trainees, for example, did not talk at all through card sorting or scheduling, even when prompted by the interviewer. However, the pattern emerging from the present analyses describes the microgenetic trajectory for the majority of trainees observed.

Thus, new concepts are constructed in linguistic or some semiotic form first; then, once internalized, these concepts can be integrated with non-verbal mental

activity, such as the application of new concepts toward problem-solving strategies. As depth of knowledge and breadth of experience increases, the structure of discourse changes. When individuals express or externalize integrated concepts, connectivity, modal flexibility and hedging against alternatives become more pronounced. Finally, acquired concepts and strategies are coordinated with pre-existing, parallel conceptual systems.

The purpose of this results section is to provide transcript excerpts and written schedules as examples of verbal and non-verbal performance among trainees in different stages of this process. Figure 21 displays the scheduling "A" question exactly as presented to trainees in pre- and post-training interviews. The scheduling "A" probe is selected here for qualitative analyses because the materials were presented in identical form both before and after training and because scheduling requires integrating backward scheduling and item structure concepts in MRP.

In the first case presented in this section, verbal performance runs ahead of non-verbal performance, representing trainees in transition. In the second case the trainee generated a transitional schedule in the pre-training interview, but in the post-training interview, non-verbal performance had been integrated with verbal performance for full expression and implementation of time phasing. The data from the post-training condition show conceptual integration. Finally, in the third case, the trainee began the training program with intuitive MRP and production coordinated concepts. This trainee's verbal and non-verbal post-training performance reflects internalized knowledge.

"Leigh" exemplifies trainees who in pre-training interviews constructed classic production schedules. He is a manager in his late forties and has worked at the plant for over twenty years. Results in Sections I show that almost all trainees demonstrated progress on MRP knowledge in post-training interviews, while results in Section II reveal that some trainees advance faster. Term analyses revealed that Leigh used "lead time" correctly, but only stated the MRP term "level." Discourse surrounding scheduling contained 77 relevant problem-solving propositions; 28 propositions were coded into the "Given" category and the remaining 49 propositions were all related to Production. Propositions relating to the Givens were associated with 13 discourse markers; 55 discourse markers were coded in Production propositions. As expected for all trainees, the concentration of discourse markers associated with Production propositions was high. The following is an excerpt from the pre-training interview transcript, to illustrate the quality of production discourse.

After a period of time spent silently scheduling the item "A," Leigh was asked by the interviewer to say aloud what he was thinking:

Interviewer: So what are you thinking now I'm curious do you mind I mean you're counting the—

Production it *racks this way/

Production it's slow/
it works like this/
*if that's the case /

Production **you** can't do anything in January/
Given **because** D takes 2 months to get/
Production **so** January is actually lost /
if you want/

Production **so you're** not going to start finishing any pro- products **until** the end of February/

Interviewer: Okay

Given **if** [?] 200 done by August/
and **you** wanted to do it/
you would take in--**you** can't start **until** here right/

Interviewer: right

Production 1 2 3 4 5 6 divided by 200 is how many/
Production **you** would have to do each month...

Interviewer ok

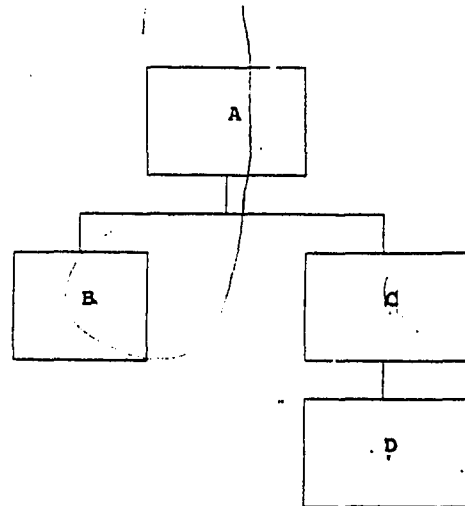
...to make **your** finished schedule 200 by August/

* MRP and Production terms are underlined.

* **Discourse markers are in bold.**

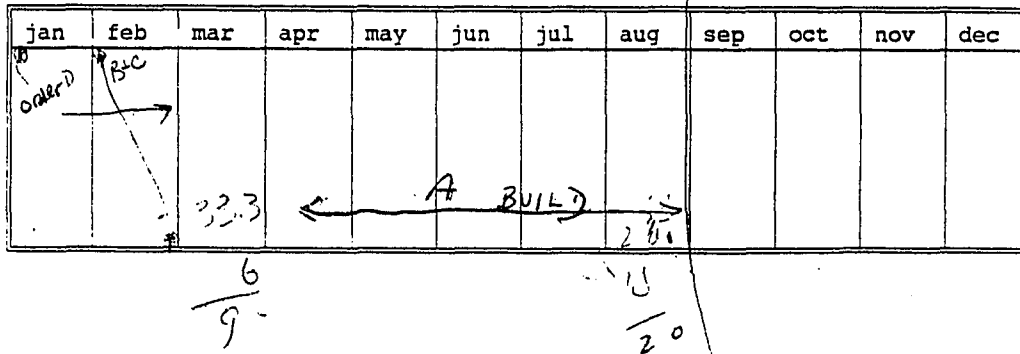
From this excerpt, it is evident that Leigh's goal was to start as early as possible on the calendar and to move slowly, "...it's slow..." through time. The origins of this strategy lie in issues of labor capacity. Scheduling large quantities to be produced in short periods of time may be optimal for keeping low inventories, avoiding obsolescence and, most importantly, better cash flow, but spreading work out across time is optimal for labor. Keeping the floor running at a consistent pace is essential in the real world of production, a construct MRP does not consider. From the MRP and production coordinated perspective, MRP is used as a tool to generate rigid plans, which are then modified by human beings to accommodate real world constraints. The goal for trainees is to understand MRP well enough to judge the output in the real world of the plant and ultimately manipulate and adapt the system and its output for the particular context in which it is running.

Figure 27.



Item Number	Description	Relative Level	Lead Time	Quantity Per
A	A	0	2 months	
B	B	1	1 months	1
C	C	1	1 months	1
D	D	2	2 months	1

Schedule Item A and all of its components so that an order for 200 of the finished good A can be shipped in August.



200 dbe

Figure 27 displays Leigh's pre-training written schedule. Again, a classic production schedule is reflected by the use of the entire calendar and the assembling of the finished good spread over the maximum amount of time. However, although Leigh's verbal and non-verbal solutions are production oriented, they are not entirely negligent of the MRP item structure information offered by the diagram on the probe sheet (see Figure 21), compared to some trainees. Several trainees did not consider this information at all, others assigned concrete products to the abstract items represented by the letters A, B, C, D, and a few trainees even imputed the letters with transformation and resource management concepts: A for material, B for transportation and C for labor.

On post-training scheduling, Leigh received a verbal performance score of four. During his interview he used five time-phasing terms, and he used "level" and "lead time" correctly. His post-training discourse contained 52 relevant propositions of which 35 related to the "Givens," 9 to Production, and 8 to MRP categories, with relatively high concentrations of discourse markers associated with MRP propositions. Specifically, in three of the MRP propositions, he captured the MRP time and item integrated time-phasing concept. The following excerpt contains this discourse.

Given	A is 2 months/
Given	ok so if A is 2 months/ that means / we'd have to / what I <u>would</u> do is/
Backward Scheduling Given	I would move everything <u>back</u> /MOD this is due at the end of August?/

Given wait a second uh A is 2 months/

Interviewer: ok so how would you move it back

Given well **if you** need two months uh for this/

Interviewer: yea

Given **if** this is at the end of the month/

Given uh and A is 2 months/

Given **you** need B and C so everything/

Time

Phasing **at least** B and C has to be moved back in advance of A/

Backward

Scheduling uh I **would** move everything back/

Time

Phasing ok so **if you** start with A/

you know that/GEN

Given **if** it takes 2 months/CD

it doesn't matter /

what you have /

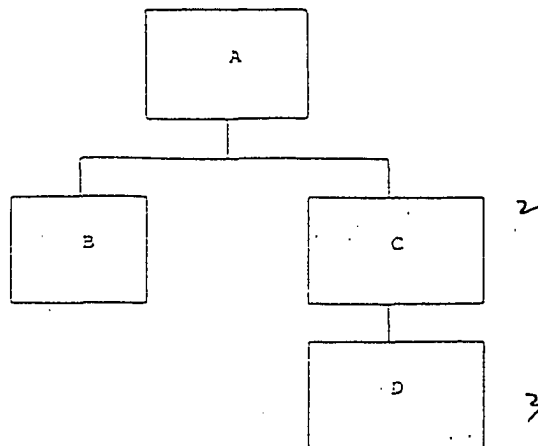
Time

Phasing **you** have to have everything **at least** by two months in advance/

Notice that in this passage, Leigh begins with the A item and works "back."

Subcomponents B and C must be scheduled "back in advance of A...you have to have everything at least two months in advance." However, in Figure 28, Leigh's written schedule does not reflect the time-phasing operation for A or D.

Figure 28.



Item Number	Description	Relative Level	Lead Time	Quantity Per
A	A	0	2 months	
B	B	1	1 months	1
C	C	1	1 months	1
D	D	2	2 months	1

Schedule Item A and all of its components so that an order for 200 of the finished good A can be shipped in August.

jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
						A	A				
					BC						
				D	D	B					

Although the attempt is clearly there, the time-phasing strategy is not achieved in non-verbal performance, while it was clearly articulated in discourse. Notice also that structurally, the discourse is marked by modal operators (the general **you**, the modal **would**, the hedge **at least**) and causal and conditional connectives, as in the time-phasing statement "so if you start ..."

Rhett is a young, college graduate, who works in the pneumatic shop as a mechanic in the "Compressor Gang," which is the team that takes care of repairing and maintaining compressors, the most complex item in the shop. Rhett's pre-training performance reflected some intuitive MRP concepts; he was, therefore, characterized as transitional. The following excerpt from Rhett's transcript contains MRP "level" and "lead time" terms stated but not used correctly and two propositions that express lot for lot quantity concepts. Notice the paucity of discourse markers in propositions containing these terms and concepts:

Given	yea <u>lead time</u> that is what/
Given	the time it takes/
Given	<u>lead time</u> is. the time /
Production	it takes to get one <u>on hand</u> /
	or that's what I'm /
Given	I'm trying to figure that out <u>lead time</u> and the <u>relative level</u> /
Production	so if you <u>order</u> everything by/
Production	that you got everything by April/

Interviewer: How would you get everything by April?

Production B: **if you** ordered D in January /

Production B: **you'd** have that by March/

Interviewer: Okay

Production B: and **if you ordered** B and C February March/
 Production B: alright **you'd** have everything/

Interviewer: Okay, would you write that in there that you would do that...

Production order D/

Interviewer: right...

Lot for Lot: order 200 B and 200 C/

Interviewer: Okay and then what would you have by?

Lot for Lot 200 D 200 B uh 200 C/

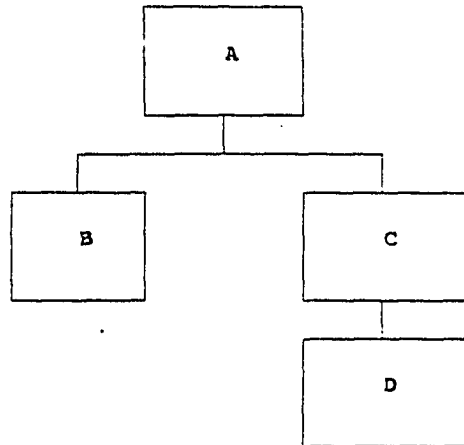
Interviewer: ok so put 200 so I know how many you're ordering

Production B: April **you would** have everything by April/GEN MOD

Although Rhett did not verbalize a plan for spreading out the production of 200 "A" items, he did this non-verbally across four months in units of 50. Figure 29 shows this written production schedule. Not unlike Leigh, Rhett also made use of the item structure information, albeit from a production orientation, in the diagram at the top of the scheduling question form. This is evident from his scheduling of D before B and C. What was not represented in the schedule was the transformation of C into D. In fact, B C and D items were implicitly treated as purchase orders, while A was scheduled as work orders for assembling B, C and D.

In post-training scheduling, Rhett advanced beyond level three verbally and non-verbally. Verbal and non-verbal scores of four were assigned to the MRP time-phased written schedule and accompanying discourse.

Figure 29.



Item Number	Description	Relative Level	Lead Time	Quantity Per
A	A	0	2 months	
B	B	1	1 months	1
C	C	1	1 months	1
D	D	2	2 months	1

Schedule Item A and all of its components so that an order for 200 of the finished good A can be shipped in August.

jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
order D 200	order B 200	order C 200	All items arrive	Schedule Production 50/mo	50	50	50				

The following passage reflects time phasing from the end item, A, due in August, back to lower level items, B and C, required by A and finally, back in time to D required by C.

Lot for Lot 200 A's by August **so** by July I'll uh.../
 Given ok no there is a two month lead time/
 Given that's 2 months 2 months to build right?/

Interviewer: yea..

Time
 Phasing **so** by June I **oughta** have all my um B and C parts/

Interviewer: and what would you do in June?

Time
 Phasing **so** I **would** begin to build in June/
 let's see ...
 Given B and C is a month **so**/

Interviewer: B and C yea B and C...

Time
 Phasing right **so** I'd have to order those by May/

Interviewer: mhm

Given **so lets** have B and C/

Interviewer: mhm...

Given D D is two months/
 Time
 Phasing **so** by March I **should** order...to have D.../

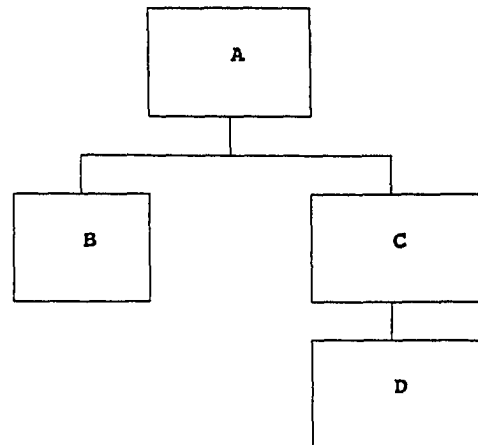
Interviewer: Should order D in March?

Time
 Phasing **so** I **could** have it in May/CS MOD

I offer Rhett's transcript and written schedule as an example of a trainee who has fully acquired the time phasing concept and who has externalized it verbally and operationalized it non-verbally. Discourse surrounding the time-phasing concept is marked by connectives and modal operators, particularly by modals and the causal connective, *so*, (in the same way the pre-training production propositions were). The discourse markers implicitly point to a range of possibilities, among which the speaker chooses. In other words, when a trainee says "I should order in March," there is an implicit reference to the fact that this is the best choice in the given situation. To know the possibilities requires experience, which is why unfamiliar concepts are rarely expressed with modal operators. Along similar lines, to connect propositions causally, temporally, contrastively or conditionally, the speaker must understand the contingencies and possibilities of the domain being discussed. Therefore, it is significant that this trainee's speech is marked this way.

In the non-verbal solution, it is particularly striking that lot for lot quantities were taken for granted, (see Figure 30). He did not even write in the quantities on the calendar. Furthermore, he didn't actually verbalize the distinction between work and purchase orders for B, C and D items, but he wrote "make C, have B & C, build A" on the calendar. Thus, in this case, the semiotic mediation and conceptual integration had taken place, and problem-solving, here, was a matter of operationalizing and externalizing the conceptual system.

Figure 30.



Item Number	Description	Relative Level	Lead Time	Quantity Per
A	A	0	2 months	
B	B	1	1 months	1
C	C	1	1 months	1
D	D	2	2 months	1

Schedule Item A and all of its components so that an order for 200 of the finished good A can be shipped in August.

jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
		order D		order B make C	Have B+C Build A						

Most of the mechanics did not advance as far as Rhett. Results in Section II may lend insight into why that is. Rhett is a college graduate, under thirty-five. Age and college education were independent variables which correlated significantly with developing time-phasing concepts through training. On post-training scheduling "A" younger trainees had less traditional production experience to interfere with making a transition to the counter-intuitive MRP concepts and strategies. Furthermore, a college education was a significant factor in advancing to time-phasing and coordinated concepts, and particularly in being able to employ these concepts on the abstract scheduling "A" task in the post-training interview. Hence, Rhett's youth and college degree may be partially related to his above-average post-training performance.

In the third case, verbal and non-verbal performances of Peter, a young air brake mechanic, are analyzed. Pre- and post-training performances on scheduling reflect that Peter has internalized the time phasing concept, and he operationalized it without uttering a word to himself or externalizing the concept for the interviewer. This trainee received a verbal score of five in pre-training scheduling. The following excerpt reflects the MRP and production coordinated concepts in propositions, as Peter considered both lead times and item structure, as well as transformation and resource management realities and constraints. For example, he talks about the end item, A, first, contrary to the traditional strategy of bottom-up scheduling and forward processing. Yet, he elaborates on packaging and shipping.

Given August 1st is the shipping day ok/
 Production uh July I want my product basically to be packaged/

Interviewer: Okay

Next, he looks after B and C, accounting for lead times, while additionally considering capacity issues, spreading the quantity across two months, and adding a safety margin of ten pieces, but not interfering with the time offset:

Backward
 Scheduling alright **now** in June I'm lookin at both B and C /
 Backward
 Scheduling and B and C for May I put May/
 Coordinated May **would** be 200 **maybe** 110-

Interviewer: Okay

and same thing for C 110/

Next, he time phases the D item, while, again, integrating capacity issues in addition to quality issues of rejects and inspection:

Coordinated and uh March **would** be 100 for D/

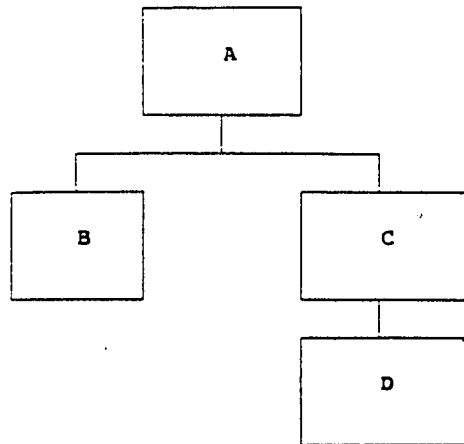
Interviewer: Okay

Production **now** the 10 **extra would** be uh for breakage/
 I **would** not-/
 i- **if you're** gonna/
 Production that way I have time to correct /
 Production whatever gets broken/
 Production **or if** there's a defect and uh/
 Production July **would** be-June **would** be the inspection/
 Production where someone **would** be inspecting the product not all of em
but randomly/

Interviewer: right

Production and **then** July **would** be package and ready for shipment out
 in August 1st/

Figure 31.



Item Number	Description	Relative Level	Lead Time	Quantity Per
A	A	0	2 months	
B	B	1	1 months	1
C	C	1	1 months	1
D	D	2	2 months	1

Schedule Item A and all of its components so that an order for 200 of the finished good A can be shipped in August.

jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
			B ₁₀₀ C ₁₀₀ D ₂₀₀	B ₁₀₀ C ₁₀₀		X	①				

✓

In the written schedule, (see Figure 31) Peter employed backward scheduling and even noted "pack" in July; however, he failed to schedule A at all and to time phase the D item. What the discourse reflected in terms of redundancy and the concept that C is transformed from D, the written schedule refuted.

In post-training scheduling, Peter uttered a total of two propositions. The entire transcript from the tape recording of this task is presented here:

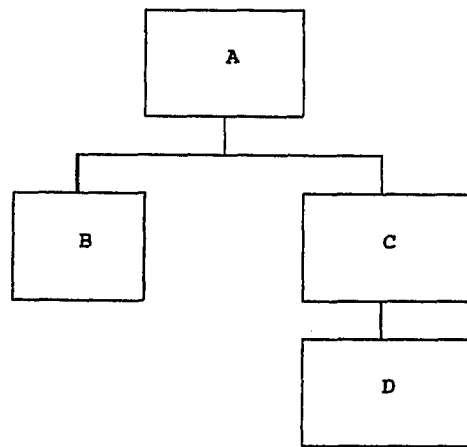
Given two months lead time/

Interviewer: is something bothering you?

Backward
Scheduling yea everything has to be behind A/

Figure 32 shows Peter's written schedule, which received a score of four. This schedule is perfectly time phased, yet shows a regression from pre-training performance in coordinating production realities and constraints with the ideal schedule generated by MRP logic. In pre-training, Peter made use of his production knowledge and some intuitive MRP concepts, probably mediated by the structure of the scheduling question as presented. In other words, he had scaffolded the MRP terms and implicit concepts presented on the worksheet and by the interviewer with existing production knowledge. His post-training verbal and non-verbal data reflect an isolation and internalization of the time phasing concept. While the training workshop was designed for trainees to construct coordinated MRP and production concepts, trainers did isolate MRP concepts. In these data, isolating MRP from production

Figure 32.



Item Number	Description	Relative Level	Lead Time	Quantity Per
A	A	0	2 months	
B	B	1	1 months	1
C	C	1	1 months	1
D	D	2	2 months	1

Schedule Item A and all of its components so that an order for 200 of the finished good A can be shipped in August.

jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
				200 B	200 A						
		200 D		200 C							

appears to be a step in the microgenetic process. However, there may be other contexts for conceptual system development that give rise to different patterns. Furthermore, for these trainees, using the system on the job is necessary for deeply and flexibly coordinating MRP and production conceptual systems.

The MRP system had not been implemented by the time we finished our post-training interview phase. In fact, today, it has been four years since we began the project, and the implementation is still in a pilot phase within one area of the pneumatic shop. Thus, there was no opportunity through interviews and observations to capture the effect of implementation in the actual workplace on trainees' discourse and problem-solving patterns on the job. Nonetheless, although the ethnographic phase of the research took place before pre-training interviews and training workshops began, researchers from the Laboratory for Cognitive Studies of Activity were constantly circulating through the shop floors and between offices of managers and analysts at the electric bench and pneumatic shop over the course of our two year tenure in this transportation facility.

One day a mechanic we'll call "Rita," who had just participated in a training workshop, called me over to show me her "levels." She said, pointing to some components on her work bench, "Look, look, these are my level two's; these are my level one's; and this is my level zero." This statement reflects an effort to integrate the MRP item structure concept with her tools, materials and activities, as well as an

insight into the direction of developing MRP and production coordination in the real workplace. The terms were used correctly and the focus of the propositions was on the new MRP concept. That is, Rita did not say, "...these gaskets are my level two's...this valve is my level one..." The non-syntactic anaphora was related to production and not MRP. However, the full MRP item structure concept would have been expressed from a top down perspective; Rita's transformation concept of bottom-up processing interfered.

This passage reflects a transitional stage of a different sort, one that has not been entertained in this dissertation thus far. There may be structurally different developmental trajectories toward conceptual coordination. A serious question for further research is to investigate the possibility of conceptual coordination that bypasses isolation of the new system before coordination. Development of this nature may occur when the individual enters a workplace where the majority of employees' conceptual profiles are coordinated. An analogy may be drawn to bilingual communities where children acquire two languages simultaneously. The present study has investigated the consequences of training on a new technology, and is, therefore, a study of sequential conceptual system acquisition. A research program for comparing sequential and simultaneous acquisition of coordinated conceptual systems is the next step.

CHAPTER 5.

DISCUSSION

"Language can never be neutral, that is, it imposes a view not only about the world to which it refers but toward the use of mind in respect to this world. Language necessarily imposes a perspective in which things are viewed and a stance toward what we view. It is not just, in the shopworn phrase, that the medium is the message. The message itself may create the reality that the message embodies and predispose those who hear it to think about it in a particular mode" (Bruner, 1986, p. 121-122).

In this dissertation a methodology for tracking semiotic mediation and discursive reorganization was developed. The resulting analyses have indicated that the relationship between language and thought in development is bi-directional in that language plays a significant role in both mediating and reflecting thought and logical operations. It was hypothesized that language would lead thought in conceptual development, beginning with terminology and continuing with increased expression of novel concepts in discourse before non-verbal application in problem-solving activity. In addition, it was hypothesized that integrated understanding of novel concepts would be reflected by heightened uses of modal operators and connectives associated with discourse surrounding the novel conceptual system. Therefore, the structure and content of discourse was expected to change in specific ways with respect to non-verbal activities in the development of a novel conceptual system. Finally, the ultimate step in this microgenetic process was hypothesized, based on previous research, to be the coordination of the newly developed conceptual system

with pre-existing, related conceptual system(s).

The trainees observed in this study were employees in a remanufacturing plant that was planning to implement MRP, which is a technology that carries with it unique terms, concepts and calculations. MRP is a theoretical approach to manufacturing (or in this case re-manufacturing) that has been instantiated in a software system. For most trainees in this study, the MRP strategies introduced in the training workshop were unfamiliar and in some cases counter-intuitive. Therefore, the introduction of MRP terminology, concepts and strategies afforded a window into the development of new MRP knowledge from the outset. It was hypothesized that exposure to MRP terms and language would be the entry point into the new system and that the structure of discourse would change with an increased and deeper understanding of the MRP concepts and strategies provided through constructive activities in the training workshop.

The training workshop was designed to engage trainees in activities that would lead them to construct MRP concepts and to give trainees a production context (the starship factory) within which to integrate these MRP concepts. In this way, trainees would come away from training with a coordinated model for MRP and production. It was hypothesized that production knowledge would first support novel MRP concepts, much in the way that production supported the intuitive MRP concepts demonstrated by "Peter's" pre-training performance as presented in the qualitative results Section III. Later, upon discovery of discrepancies between the two systems, MRP would be isolated and internalized, also exemplified in "Peter's" post-training

verbal and non-verbal performance. This is also evident from the post-training card sorting analyses of item structure concept expression and operation in verbal and non-verbal performance: the results reflected a dramatic decrease in mean number of propositions from pre- to post-training interviews as well as a convergence of verbal and non-verbal performance scores. It was hypothesized that coordinating MRP and production would be the final step in the microgenetic process.

Hence, the development of coordinated knowledge was the object of inquiry, and the following pattern emerged from analyses of the data from this study.

1) Scaffolding: Trainees first attempted to use existing production knowledge to support new MRP terms and concepts. Trainees also talked aloud through problem-solving activities at a more advanced level than their non-verbal strategies; as MRP concepts became integrated, talk decreased. The structure of trainees' discourse surrounding existing knowledge was qualitatively different than the structure of discourse surrounding transitional concepts.

2) Isolation: As MRP knowledge advanced, trainees approached the interview tasks from a purely MRP perspective without making allowances for capacity and quality, as they had before advancing toward MRP conceptual development. Trainees constructed complex concepts within the MRP system, such as time phasing, by integrating two or three simpler MRP concepts. As the new MRP concepts were

integrated and internalized, the structure of trainees' MRP discourse was marked with connectives and modal operators in a qualitatively similar way as discourse surrounding pre-existing production knowledge.

3) Coordination: Trainees who could consider production constraints and realities in implementing MRP scheduling or card sorting strategies had reached the coordinated level.

In previous research (Zazanis & Glick, 1992), significantly higher proportions of MRP and production coordinated propositions were found in the discourse of workers from a plant in which MRP was running successfully (called "Intek") compared with workers from a plant in which the MRP system was failing (called "Kemps"). The MRP and production coordinated propositions were also associated with coordinated non-verbal performance on card sorting and scheduling tasks, which were identical to the tasks presented in the present study. As discussed in the introductory chapter of this dissertation, an analogy was made between coordinated MRP and production propositions and intra-sentential code-switches in bilingual conversations. One of the goals of the present study was to trace the development of these coordinated propositions discovered at Intek and, to a lesser extent, Kemps.

Vygotsky (1986) compared acquiring scientific concepts and integrating them with the spontaneous to "learning a native language and a foreign language...The analogy with learning different languages goes beyond a superficial similarity for it

reveals psychological relations that are actually akin to those existing between scientific and spontaneous concepts" (p. 159, *ibid.*). Vygotsky explained that second language acquisition "uses the semantics of the native language as its foundation," (p. 160, *ibid.*), yet renders the first language more abstract.

"One may say that the knowledge of a foreign language stands to that of the native one in the same way as knowledge of algebra stands to knowledge of arithmetic, enhancing it and turning it into a concrete application of the general algebraic laws" (*ibid.*).

The general assumption in Vygotskian theory is, thus, that to develop higher mental functions is to achieve a higher level of abstraction, whether it be in the realm of science, literature, art or otherwise.

When we look at the development of new technological knowledge based on a theory of manufacturing, we are looking at scientific concept acquisition among adults. Vygotsky described scientific concept acquisition as a top down process beginning with verbal definition. "In the case of scientific thinking, the primary role is played by initial verbal definition, which being applied systematically, gradually comes down to concrete phenomena" (*ibid.*, p. 148). For the trainees in the present study, the "initial verbal definition" started in the pre-training interview and continued in the training workshop. It was originally predicted that terms introduced in the training workshop would mediate the core MRP concepts. However, careful consideration of

the pre-training interviews revealed that trainees were first introduced to MRP terms and concepts when presented with card sorting and scheduling tasks before the training workshop. And it was there that trainees began to state the MRP terms for which they would ultimately develop meaning within the MRP system.

Empirical support for the mediational role of terms is found in research on word learning for school children and adults (Anderson & Nagy, 1989; McNamara & Miller, 1989; Gildea, Miller & Wurtenberg, 1990). It is evident that words are gradually endowed with meaning through multiple encounters in different discursive contexts. Data from the present study support the claim that term production precedes comprehension. Furthermore, for the trainees in the present study, certain terms would acquire multiple meanings through multiple encounters. For example, "level" is an MRP term that denotes an item's place in the item structure of a finished good or end item. "Level" is also a term in the English language with other referents. Nelson (1991) has drawn distinctions between different components of a term, including the phonetic form and the denotational meaning. Trainees in this study would find that familiar denotational meanings of "level" did not make sense in the context of the probe materials. In fact, in workplace jargon, it is often the case that familiar phonetic forms have exclusive denotational meanings, so that individuals entering that workplace must derive the exclusive meaning from the familiar phonetic form of the term. Conclusively, then, terms (both familiar and unfamiliar) pointed to new meanings which were then derived by trainees through use in the MRP domain where the meaning is made.

Term mediation occurred for trainees in this study during pre-training interviews and training workshops. The terms then paved the way for the internalization of word meanings. These word meanings were integrated and ultimately applied to problem-solving. Talking aloud through problem-solving activities was taken as a sign of the transition from externally mediated to internally constructed meaning. As the mediated terms and concepts were internalized, the need to talk aloud through problem-solving activities decreased, much in the way Vygotsky (1986) characterized the internalization of speech among pre-school aged children and thus the disappearance of egocentric speech.

On the topic of the relationship between language and thought in child development, Vygotsky claimed that "...up to a certain point in time, the two [speech and thought] follow different lines, independently of each other...At a certain point, these lines meet whereupon thought becomes verbal, and speech rational" (p.83, *ibid.*). In the present study a similar microgenetic pattern was observed among adult trainees acquiring the MRP conceptual system and language. Verbal performance scores averaged higher than non-verbal performance scores through the transitional process until MRP concepts were fully internalized and integrated, when verbal and non-verbal scores converged. In problem-solving activities, the use of MRP concepts in discourse propositions ran ahead of the application of the concepts to MRP strategies. Trainees' verbal performance scores averaged higher than non-verbal performance scores in pre- and post-training Intek card sorting and all scheduling tasks. However, in the post-training Ship card sorting condition, most trainees

generated MRP sorts, and verbal and non-verbal performance scores converged. This points to the full integration of the mediated concepts with mental activity, probably facilitated by the training workshop in which the Ship was actually used to construct item structure concepts.

The analyses of discourse for terms and propositional content reflected the mediational role of language; the analysis of discourse structure reflected conceptual achievement. As shown in the review of discourse structure concepts in Chapter 1, reference to underlying knowledge is marked by connectives and modal operators. The assumption underlying these analyses is that discourse can only represent the surface of a domain in communication. For a given individual, the underlying volume of knowledge could be thin, or it could be a deep, integrated mass. Because discourse markers express conceptual contingencies, temporal sequence, ranges of possibilities within a domain, as well as constraints and generalities, high concentrations of discourse markers surrounding propositions related to a particular domain reflect depth of knowledge and experience therein. As expected, trainees drew on "cognitive support" from the familiar production knowledge system before acquiring MRP concepts. High concentrations of discourse markers were associated with production propositions, reflecting the externalization of deep, integrated knowledge. After the training workshops, where trainees applied MRP concepts to simulated production activities, post-training interviews showed an increase in discourse markers associated with MRP propositions. This increase reflects the construction of a cognitive context for MRP, as well as the integration of concepts within the MRP domain.

In summary, the discourse content analysis in this study revealed how "speech becomes rational" (Vygotsky, 1986, p. 83) in the microgenetic process; the discourse structure analysis reflected how "thought becomes verbal" (ibid.).

Glick (1995) explains that "abstract knowledge is generally considered a telos for development, and if not for developing children, certainly for developmental theory" (p.362). In the Laboratory for Cognitive Studies of Activity a research program was designed to understand development in the context of activity and to consider the "telos" as shaped by the particular context in which individuals are developing. Scribner (1986), who founded the "Lab," had adopted an activity theory perspective, extending beyond the scope of Vygotsky's theory in which "the most developed is the most abstract" (Glick, ibid). From this perspective, the original workplace studies were designed and continued long after Scribner died. It was under Scribner's original direction and subsequently under Glick that the Lab set forth on a quest for understanding coordinated knowledge systems in the workplace. In this research paradigm, data is allowed to speak to researchers after it has been collected, and the assumptions in the original design of a study are candidates for reorganization.

The present study held as a telos the coordination of MRP and production knowledge. In analyses thus far, there has been a common trajectory across all trainees – that new MRP concepts are consistently expressed in discourse before they are utilized in problem-solving tasks. The difference between trainees, although there were only 30, was a matter of pace. That is, trainees began to develop new MRP concepts by using MRP terms that they picked up in training and/or interviews. With

further development, new MRP concepts were isolated and expressed propositionally. Subsequent integration led to heightened uses of discourse structures that reflect deeper understanding with a simultaneous development of the ability to operationalize the new MRP concepts in problem solving tasks. Finally, trainees reached the point of being able to coordinate MRP and production, commenting on MRP from a production perspective, and not only recognizing how the system may be used to enhance efficiency but also how it must be monitored for unrealistic recommendations.

The logic underlying the choice of coordination as telos derived from previous studies of manufacturing plants, where it was found that success with MRP relies on well-distributed coordinated MRP and production knowledge. An individual, who works in a manufacturing plant running MRP, and who has insufficient knowledge of the "practical" production system, will make mistakes no less destructive than the individual who has insufficient knowledge of the more "formal" MRP system. In fact, trade journals repeatedly stress that at least eighty percent of the workforce in a plant must have a flexible understanding of MRP data structures and operational logic only for a moderately successful implementation.

The question is whether or not this pattern is robust under different circumstances. Future research along the following lines will serve to inform this question.

- 1) Is it necessary to abstract the MRP conceptual system from production or can

coordinated knowledge systems develop without isolating the target system to be acquired? Perhaps it is not the case that all individuals with MRP and production coordinated knowledge acquired MRP knowledge prior to the coordinated form. A re-analysis cannot address this question for two reasons: a) Few trainees reached the coordinated level in verbal and non-verbal performance; and b) the coordinated level that was observed in these data involves a limited range of concepts, since the MRP implementation in the real work place had not begun. The issue of evaluating MRP recommendations for "real" work and purchase orders could not be examined. Coordinated concepts expressed or operationalized by the trainees in the present study were limited to item structure and "real" parts/finished goods in the plant or time phasing vis a vis capacity issues in labor and tools. Hypothetically anticipating how the MRP system's recommendations may be reshuffled in the context of an interview is very different from actually releasing or rejecting planned orders to the floor.

2) Do the telos of coordinated knowledge and the developmental trajectory toward this telos change when the setting is qualitatively different? For example, the assumption on Vygotsky's part in drawing an analogy between scientific concept development and second language acquisition is that the process is sequential. The simultaneous acquisition of two languages, however, may not lead to the same level of meta-linguistic abstraction. The goal of bilingualism might be to communicate in a bilingual community. In this case the process of acquisition and the structural and

functional forms ultimately developed will be different than in cases of sequential acquisition in which the goal is to interact intellectually with monolingual speakers of the targeted second language. Analogically, if an individual enters a workplace in which coordinated knowledge is already pervasive, will this microgenetic trajectory follow a different course than that of an individual who works in an environment where a new knowledge system is introduced at large (as was the case in the present study)? While the MRP implementation observed in the present study afforded an opportunity to investigate some aspects of the relationship between language and thought in adult development, further investigations into the relationship between context and microgenetic trajectory require varied settings in which comparisons can be made between individuals who enter "coordinated workplaces" and individuals working in environments where implementation is about to begin. I expect that the pattern of individual development of a technological conceptual system will be contingent upon the relationship between the organization's stage of technological implementation and individual entry point into that organization.

In the present study, where the conceptual system investigated was new to the employees in this remanufacturing plant, the emergent microgenetic pattern of 1) mediation and scaffolding, 2) isolation and internalization, and finally 3) coordination, was reflected among all trainees. Some moved more rapidly than others through the process; certain trainees entered the training process with intuitive MRP concepts. While there were individual differences observed in "self-scaffolding" through private speech, in no case was there a deviation from the sequence of conceptual

development outlined in this dissertation. In conclusion, the method developed for analyzing discourse content and structure was effective toward measuring conceptual mediation and integration, and the results point to a microgenetic trajectory that merits exploration in a variety of contexts.

Appendix A.

Pre-Training Interview

The questions that follow concern information that we are seeking for our research on work and learning in the work-place. If for any reason, you do not want to answer a particular question, simply go on to the next one. All of our research will be displayed in general findings, and confidentiality to persons involved is guaranteed.

Name: _____

Current Job Title: _____

Department: _____

Age group: under 25 _____
 26-35 _____
 36-45 _____
 46-55 _____
 over 55 _____

What is your country of origin? _____

What languages do you speak fluently? _____

What is your educational background? Please fill in the chart below, indicating what levels of formal education you attained, what you studied, when, and where:

	Have you attended courses at:	Did you complete a degree?	What subject area did you study?	What years did you attend?	Where did you attend?
Highschool	yes ____ no ____	yes ____ no ____			
Vocational or Technical	yes ____ no ____	yes ____ no ____			
College	yes ____ no ____	yes ____ no ____			

Have you taken any courses or workshops that are specifically related to the work you do?

yes ____ no ____

What were they and when did you take them? Please fill out the chart below:

What was the title of the workshop or course?	How long did it last? A week? More?	Did it result in any kind of certification? What?	Did your employer pay for the course?	When did you take it?

How many years have you worked in electronics? _____ mechanics? _____

Please list the jobs you had before you came to the Transit Authority:

Job Title	Type of Company	For how long, and when?	Briefly describe what you did

When did you start working at the Transit Authority? _____

What jobs have you held in the Transit Authority? Please fill out the chart below:

Job Title	Department	For how long and when?	Briefly describe what you did

Do you currently use or access any computer system on your job? yes___ no___

If yes, which ones? _____

If yes, do you access them to gather information_____

to check information_____

to input information_____

Have you had any on-the-job training about the computers in your work-place?

yes ___ no ___

Have you attended any courses or workshops about the computers in your work-place?

yes ___ no ___

Please list all computer-oriented courses or on the job training, and note when:

Have you ever heard of MRP? yes___ no___

1. If the informant reported any vocational training or education, ask him/her to describe it.
2. Would you describe your job(s) since you have been with the T.A. For example, what was your first job and what did you do on that job?
3. Do you find that any part of your education assists you on your present job?
 (If yes) How is that?
 (If no:) Why is that? Can you go into more detail about why you think it doesn't help that you went to school?
4. What are your responsibilities and goals on your job.
 What do you do to accomplish these goals/responsibilities?
 I'm still not getting it, could you take me through a typical day?
 (Probe on "how" and get details about artifacts used)
5. It seems it would take a lot of knowledge to do this job, where did you get it?
6. I really want to get a clear picture of what you're telling me. would you describe a typical problem that you encountered on the job recently and then tell us how you solved it?
 (If informant is a supervisor and gives an answer in which "people not working" is a problem, follow up with:)
 How did you know where to begin? [with that solution]
 What about a technical problem, concerning, say ... a ...? [list things that have been identified by the individual]

 (If informant is a technician, follow up with:)
 How did you know that this was a problem? If it were me in that situation, I'm not sure I would have noticed this.
 How did you know where to start looking for a solution (or source of the problem)?
 In retrospect, can you think of other ways the problem might have been solved? by, for example, another person with a different perspective than yours?

7. Have you had a problem you needed help to solve -- where you had to get another opinion, or some help, for example?

What kinds of things did you try first that led you to realize you needed another's point of view?

8. What tools/materials do you use to do what you have to do?

Have you ever had to make or modify tools so that they worked better?

9. When we toured the shop floor, we noticed that many of the workers had notes, diagrams or devices that they used in their work.

Do you have any of these things?

(If yes) Please describe what you have.

In what ways do you find them useful?

Did you make any of these things?

(If yes) would you describe them?

Did you make any devices now used by others?

10. What kinds of information do you use and how to you get it?

Do you get any information, verbally, written or on a computer screen?

(if still not understood) Things like, a schedule you refer to, somebody telling you to do something, a list you might keep for yourself, procedure sheets from engineers.

11. Do you receive your schedule daily, weekly, monthly?

Is it a reasonable schedule for what needs to be done?

How do you organize your activities in terms of time?

12. How do you make sure you have all the materials and tools you need for a job?

13. How are the materials you need ordered? Would describe the process to us.

14. How do you anticipate what you will be needing in the future?

15. What are the existing computer systems here? What is your idea of their function, purpose and operation?

If informant says "I don't know" follow with:

1. We've heard there is a Talon system. Are you familiar with that?
What do you know about it?
2. We've heard there is a CMS system. Are you familiar with that?
What do you know about it?
3. We've heard there is a program for keeping track of overhauls. Are you familiar with that?

What do you know about it?

4. Is there anything else that is used?

16. Some people have said that reducing inventory is better while others say that the best way to be prepared is to stock up on parts you might need. What do you think of these two ideas?

17. (using stapler)

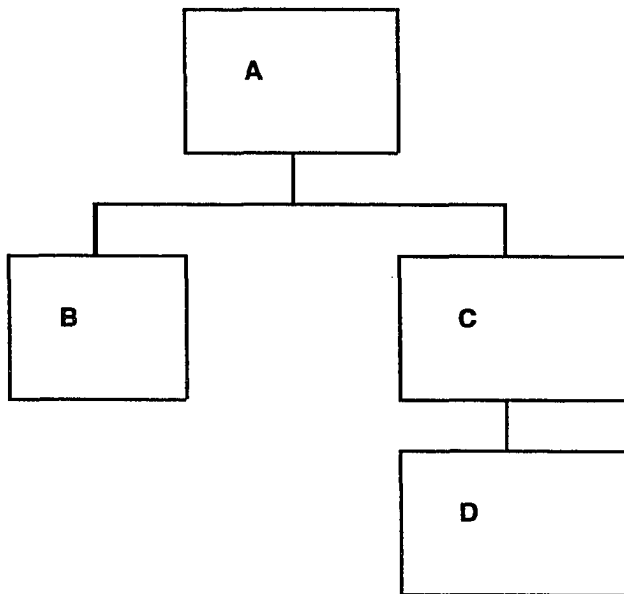
What are the parts in this machine? (list them)

How would this be manufactured/made?

Looking at this part, could you anticipate how it might be likely to break or need repair?

How might it be fixed? or remanufactured?

18.



Item Number	Description	Relative Level	Lead Time	Quantity Per
A	A	0	2 months	
B	B	1	1 months	1
C	C	1	1 months	1
D	D	2	2 months	1

Schedule Item A and all of its components so that an order for 200 of the finished good A can be shipped in August.

jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec

19. **Card sort**
Cards containing names and numbers of a finished good not made in the plant with additional information that reveals how the part would be organized according to an MRP II structure are presented. The informant is asked to sort the card in an order that would make sense in terms of how this "mystery" part should be made.

After informant has sorted the cards, put the end item card on the table and indicate that some people sort with this card at the "top" with others arranged below. Ask how the informant would accomplish this with some logical consistency.

(After informant arranges cards, arrange them yourself with the end item at the top, and the "used in" cards placed properly on proper levels). Ask the informant "does this make any sense to you?"
20. Using this diagram as a reference what is the total number of parts needed to make up 20,000 A's? (see attached).
21. Please describe the overhaul of a car from beginning to end.
If you had to organize the overhaul, what kinds of things would you have to think about?

What kinds of information would you need to have?

(If he or she doesn't mention computers in the reorganization of overhaul, ask:)
What would you want to have computerized, if anything?
22. Suppose you could have a computer system especially suited to your job and work-place.

What would you have it do?
Who else would have access to it?
23. Is there any tool or machine or part that you would like to change or improve? How would you change it?
24. In terms of production practices and the division of tasks, are there any changes you would make to the way things are done? Anything you would like to see improved?
25. You volunteered to take the MRP II workshops. What do you expect this computer to be doing?

How do you think it will be integrated with your job?
How will you use it,
What impact will it have?
What kinds of adjustments to you think people will have to make with this system?
26. What if you were to give someone an overview of manufacturing, what do you think would be important to tell them?
Any general ideas or principles?
27. If you could change just one thing in this place, what would it be?

Post-Training Interview

Name _____

Date _____

Latin Square Order _____

1. Suppose you have been working with a trainee for several weeks, showing them what to do. You have to decide whether they are ready to work on their own. What questions would you ask a trainee to see if they knew enough to work on their own? How would you tell if they are ready or not?
2. Construct an MRP item structure that makes both production and MRP sense to you, using this pen (standard ball point).
3. Card Sorts - Intek and Starship
4. Scheduling - A, Ship and Pen (See Figures 21, 22, and 23)
5. Using this tree diagram as a reference, how many parts does it take to make A?
6. When you ask the system what's on hand, does it tell you what's in the bin/on the shelf or something else?
7. What's the difference between planned orders, firm planned orders and released orders?
8. What is MRP?
9. What are you using MRP for?
10. What impact is MRP having here? (If none yet, what impact will it have down the line?)

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