The Development of Dynamic Skill Theory

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Note. We dedicate this chapter to the memory of our friend and colleague, Robbie Case, who died too young in the midst of a good, strong, productive life. Preparation of this chapter was supported by grants from Mr. and Mrs. Frederick P. Rose, Harvard University, and NICHD (grant #HD32371).

To appear in R. Lickliter & D. Lewkowicz (Eds.), Conceptions of development: Lessons from the laboratory Hove, U.K.: Psychology Press.

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In this age of focus on mind and brain, the complexity of the human mind is clear, as in this common bit of wisdom:

> The earth is very complex, but the sky is more complex. The sky is very complex, but the universe is even more complex. The universe is very complex, but the human mind is by far the most complex.

How can we understand development of human beings' minds in all their complexity, richness, and diversity? The conventional wisdom is to **dissect** a living system so that people are able to study the system one motionless piece at a time. Can we understand, for example, children's interactions, understandings, and feelings in their family by dividing memory, social roles, norms, and learning contingencies and analyzing them separately? This paradigm has so long dominated most of the behavioral, developmental, and educational sciences that people are accustomed to viewing many human characteristics such as children's intelligence or adults' emotion as fixed, clear-cut, and unconnected entities.

With dynamic skill theory (Fischer, 1980b; Fischer & Bidell, 1998), we[1] have tried to take a different perspective. Like examining a car that is moving on the road or studying a river that is running on the riverbed, skill theory is designed to **unpack** but not dissect human development in order best to understand the development of human mind and action in all their complexity,

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[1] The first person plural will be used throughout the chapter to represent over 30 years of collaboration between the first author and his mentors, colleagues, and students in developing dynamic skill theory, including the writing of this chapter. The first person singular will be used to refer to Kurt Fischer. The major collaborators include Catherine Ayoub, Bennett Bertenthal, Thomas Bidell, Daniel Bullock, Rosemary Calverley, Joseph Campos, Ching Ling Cheng, Roberta Corrigan, Edmund Fantino, Nira Granott, Marshall Haith, Jane Haltiwanger, Helen Hand, Susan Harter, Rebecca Hencke, Jin Li, Bruce Kennedy, Karen Kitchener, Catherine Knight, Susie Lamborn, Michael Mascolo, Gil Noam, James Parziale, Sandra Pipp, Pamela Raya, Samuel Rose, Phillip Shaver, Paul van Geert, Lianquin Wang, Malcolm Watson, Michael Westerman, and many others. The theorizing process has been significantly influenced by the classic work of Piaget, Erikson, J. M. Baldwin, Hebb, Kohlberg, C.S. Peirce, Skinner, H. S. Sullivan, Vygotsky, H. Werner, and Wittgenstein, as well as more contemporary work by Mary Ainsworth, John Bowlby, Roger Brown, Jerome Bruner, Robbie Case, Noam Chomsky, Howard Gardner, J. J. Gibson, Jerome Kagan, Robert LeVine, Peter Molenaar, Robert Thatcher, Esther Thelen, Han van der Maas, Sheldon White, Beatrice and John Whiting, and David Wood.

richness, and diversity. This theory offers a **dynamic** framework for describing, assessing, analyzing, and explaining how person and world function together in human development, building on the tools of dynamic systems theory, like some other contemporary viewpoints (Damon, 1998; Fogel, 1993; Lewis, 2000; Parke, Ornstein, Rieser, Zahn-Waxler, 1994; Thelen & Smith, 1998; van Geert, 1998). As examples in the chapter, we will focus on skill analyses on children's social interactions, especially in their families, unpacking the activities, understandings, and feelings within a common framework that helps us interpret them all in place together.

A 30-Year Intellectual Journey

Like most complex theories, dynamic skill theory has undergone a long course of development within the sociohistorical context of its time. Starting from the late 1960s, it has been a 30-year-long intellectual journey in which we have actively explored human action and thought, constructively synthesized diverse perspectives and methods, and persistently linked theory to method and data in research, all in collaboration with a number of colleagues. Our broad goal is to understand what, how, and why human beings develop and learn.

In this chapter, we will first present **how** dynamic skill theory has evolved by describing three major phases in its development:

1. Birth of the theory (roughly from the early 1970s to the early 1980s). The central theme in this phase was analyzing systematic change in the **organization** of action and thought.
2. Early growth of the theory (roughly from the early 1980s to the early 1990s). The central theme moved to examining complex **variations** in the organization of action and thought, including systematic change.
3. Later growth of the theory (roughly from the later 1980s to 2000). The central theme became explaining the constructive **dynamics** underlying complex variations in learning, development, and emotional state.

At the end of the chapter, we will analyze **why** the theory has evolved by discussing four major factors that contributed significantly to the dynamic development of the theory:

A. Following our noses: pursuing persistently a general question about development or learning while letting our observations shape our direction.

B. Opening our eyes: consistently integrating new insights and tools to further build the framework.

C. Moving our legs: actively intertwining conceptual improvements and methodological advances in empirical research to develop the theory.

D. Holding each other's hands: working closely with students, colleagues, and mentors to construct the theory in a supportive social context.

For readers who are interested in studying more about the theory, Fischer and Bidell (1998) provide a broad introduction to the framework, placing skill theory in a wider context of dynamic approaches to development and variation.

Birth of the Theory: Analyzing Change in Organization of Action & Thought

In the late 1960s and the early 1970s, the intellectual environment in the behavioral sciences in American universities was mixed: Piaget's (1970b) structuralism (constructivism) was starting to become a mainstream theoretical school, while classical behaviorism remained strong in the training of new developmental psychologists. Both behaviorism and constructivism had fundamental influence on the initial construction of dynamic skill theory. Also, in Harvard University's interdisciplinary Social Relations Department, many renowned scholars, such as Roger Brown, Jerome Bruner, Erik Erikson, Jerome Kagan, Lawrence Kohlberg, B. F. Skinner, Harrison White, Sheldon White, John and Beatrice Whiting, and Peter Wolff, were teaching a variety of theories of psychology, anthropology, sociology, child development, and pedagogy. This interdisciplinary training in theory and research made deep marks on development of the theory.

A reasonable place to mark as the starting point for dynamic skill theory is Kurt Fischer's (1970) doctoral dissertation entitled *The Structure and Development of Sensory-Motor Actions*. This research followed the behavioral tradition of conducting a series of strictly defined empirical studies of animal learning in a laboratory. At the same time, it took a new structural perspective in analyzing changes in the organization of activities as rats learned to run an S-shaped maze or pigeons learned to peck in a two-link variable-interval reinforcement schedule. In these experiments we found four distinct phases of learning (microdevelopment) in sensorimotor behaviors that were similar for both rats and pigeons – phases defined empirically by a microdevelopmental sequence of four clear patterns of activity (Fischer, 1975; Fischer, 1980a). For example, in an early phase animals began the task slowly but once they started, they performed quickly and intensely and had difficulty interrupting their actions to learn or attend to something new in the situation. In the final phase animals performed the entire task relatively quickly and could easily interrupt their actions and learn something new about the situation.

Although this discovery of change in organization with learning was exciting, it raised a major question: How could these changes be described and analyzed? There was no theoretically sound, empirically feasible analytical system for analyzing and assessing the structures that animals and people learn in such tasks. Classical behaviorist psychology had primarily examined response rates of specific behaviors in context, providing few tools for analyzing their organization. Structural-developmental psychology, including Piaget (1936/1952, 1957, 1983), Vygotsky (1962), Werner (1957), and Kohlberg (1969), had focused mainly on general developmental structures, providing few tools for analyzing change and variation in organization of specific activities. We needed a set of tools and concepts for analyzing changes in the organization of action and thought. To build a useful analytic system, we would need to bring together many components into what is now called a dynamic systems perspective. The systems theory of that time (for example, von Bertalanffy, 1968) provided promising concepts but few tools for analyzing organization and variation in specific activities. Dynamic systems theory had not yet been built in the biological and behavioral sciences. We were like an infant "groping" to find a means to our goal (Piaget, 1936/1952) – following our nose to find a way.

In the ten years after the 1970 dissertation research, we worked to devise an analytic system of new methods closely tied to theory for analyzing change and variation in development and learning (e.g., Fischer, 1972, 1975, 1980a, 1980b). The first breakthrough came with our close interpretation of specific examples of behaviors that developed in individual infants and children. At first, we used them to try to understand Piaget's explanations of stages and equilibration processes (Inhelder & Piaget, 1955/1958, 1959/1964; Piaget, 1936/1952, 1937/1954, 1946/1951). The series of advances in concepts and methods led to the formulation of skill theory, as published in the 1980 *Psychological Review* paper entitled "A Theory of Cognitive Development: The Control and Construction of Hierarchies of Skills" (Fischer, 1980b). This paper marks the birth of skill theory, the initial form of what has developed into dynamic skill theory.

In this paper, we synthesized a decade of thinking and research to produce a new theoretical framework for analyzing cognitive development and learning. Its central theme was concepts and methods for assessing and analyzing changes in the organization of individual human activities (actions and thoughts). This framework included key interconnected concepts, including skill, cognitive control, set, skill hierarchy (levels, tiers, and transformation rules), collaboration of person and environment, developmental sequence and synchrony, recurring growth cycles, task analysis, unevenness (*décalage*), task domain, skill domain, and microdevelopment. For all these, the starting point is the concept of *skill*, which is why we chose the name "skill theory."

<u>Skill</u>

Different from competence, ability, or capacity, **skill** is a concept that is context-based and task-specific. I (KF) had extensive knowledge of behaviorist concepts such as context, task, and stimulus control (Skinner, 1938, 1969), and I worked with Jerome Bruner as a postdoctoral fellow while he was elaborating the concept of skill (Bruner, 1970, 1973). In seminars and coffee shops, a group of us debated how organism and environment could work together. Focusing on analyzing specific activities of individual people or animals, we always ended up including the context as key, along with the organism's actions. We could find only one concept that directly included both person and environment in the same entity – skill. A person can have a skill for building with a particular set of toy blocks, telling a story about one's family, cooperating with mother and father at the dinner table, fighting with sister at the dinner table, operating Grandmother's sewing machine, playing tennis on a grass court, or doing analysis of variance with a computer statistics program. Concepts of ability, competence, capacity, concept, intelligence, and even scheme (Piaget, 1936/1952) did not have that meaning. Interestingly, many languages, including French, do not seem to have a word like skill for designating activities in a specific task or context. The term skill is thus the best choice.

<u>Levels and Tiers</u>

A related concept that we devised was skill **level**. Levels are not stages, because there is so much variability in each child's activities that children do not show ladder-like changes from one stage to the next at specific ages. What they do show is qualitative changes in skill organization, especially in their most complex activities. For example, at 2 and 3 years a girl represents the role of her mother as a collection or set of behaviors, such as $\left[\begin{array}{c} \mathit{JANE} \\ \mathit{MOTHER} \end{array}\right]$, and separately she represents the role of father as another set, $\left[\begin{array}{c} \mathit{WALTER} \\ \mathit{FATHER} \end{array}\right]$. She can understand and act on each role separately, but she has difficulty representing the two roles in relationship, simplifying to one role at a time. At about 4 years of age, her understanding shifts dramatically, as she represents social role relationships for the first time, relating mother to father to understand their special parental and romantic relationship, $\left[\begin{array}{c} \mathit{JANE} \\ \mathit{MOTHER} \end{array} \text{———} \begin{array}{c} \mathit{WALTER} \\ \mathit{FATHER} \end{array}\right]$. Similarly at this age she relates her role as friend to another child's role as friend to capture the relational meaning of best friend (Fischer, Hand, Watson, Van Parys, & Tucker, 1984).

The conceptions of specific skill levels grew from our efforts to determine where major qualitative changes in organization occurred by working extensively with protocols describing specific developing activities, some from our own observations and others from Piaget, Bruner, and other researchers. In the first skill development model based on these analyses, we found that the clearest changes in organization corresponded roughly with what Piaget (1936/1952, 1983) called primary circular reactions, secondary circular reactions, tertiary circular reactions, representations, concrete operations, and formal operations.

We found evidence for another level in the middle preschool years, which is similar to what Piaget and his colleagues called semi-logic (Piaget, Grize, Szeminska, & Bang, 1968) and which we call representational mappings. This mapping level marks a significant advance in negotiating social relationships in the family, as illustrated in the above mapping of mother and father roles that leads to understanding the special relationship of mother and father (Watson & Fischer, 1980; Watson & Getz, 1990) Another mapping skill that surges at this level is understanding self and other, as in the currently popular research on theory of mind (Frye, Zelazo, & Palfai, 1995; Leslie, 1987). Various descriptions and theories proposed other stages or substages, but for those we found less convincing empirical evidence of abrupt qualitative change from one step to the next (Fischer, Pipp, & Bullock, 1984).

Piaget’s descriptions of each of these “stages” provided a good starting point but did not adequately capture the organization in the many examples that we examined. Gradually we invented a different way of describing the structures, which we introduced above in the skill diagrams for mother and father roles. This tool is based on the concept of skill defined in terms of a few simple kinds of relations among skill components – mappings (———), systems ($\longleftrightarrow$), and systems of systems ($\Longleftrightarrow$); brackets mark a distinct skill. The skill components are **sets**, not points, because they always include a number of adaptations of activities to a particular context. An example is the skill for the mother-father role relationship, $\left[\mathit{JANE}_{\mathit{MOTHER}} \text{ ——— } \mathit{WALTER}_{\mathit{FATHER}} \right]$, which involves relating two sets through a mapping. We will only sketch a few ideas from this analytic method here. A full explanation is available in other sources (Fischer, 1980; Fischer & Farrar, 1987; Fischer & Bullock, 1998).

We also sought clearer, more explicit ways of defining levels empirically, ways of specifying the dramatic changes that we had seen in the many developing activities that we had analyzed. Eventually we found that discontinuities in growth curves, such as spurts and drops, provided an excellent empirical criterion for emergence of a new level, with clusters of spurts occurring at certain age periods. An excellent example is the growth spurts in vocabulary, sentence production, and pretend play late in the second year in most toddlers (Corrigan, 1983; Reznick & Goldfield, 1992), as illustrated for personal pronoun vocabulary for the Dutch child Tomas in Figure 1 (Ruhland & van Geert, 1998). Another is the spurts in understanding family roles, friendships, and self-other relationships (theory of mind) at ages 4 to 5 years.

<u>Insert Figure 1 about here</u>.

In describing the series of skill levels in infancy and early childhood, our main conscious metaphors were chemical structures (which inspired the skill diagrams) and building blocks. A characteristic of these kinds of structures is that smaller units become components of larger structures. In the same way each new level of skill involves combining two or more units from the prior level to form a qualitatively different kind of skill structure, as the isolated roles of mother and father at one level are combined to form the skill for mother and father in relationship at the next level.

The evidence pointed to a series of levels, initially seven that we could identify between four months and 12 years of age. We also found what seemed to be further structure within the series – a cycle of levels that we called a **tier**. The first hint of a tier came from the dramatic changes that occur late in the second year with the emergence of the level of representations. We hypothesized that a higher order of structure emerged at that level, similar to a new building block that can be constructed from simpler building components. With the emergence of such a new structure the cyclical building process of levels starts over again, starting once more with single sets and developing through relations among sets (mappings, systems, systems of systems). Figure 2 illustrates this **growth cycle** with the building-block metaphor.

Insert Figure 2 about here.

In forming the new building block at about age 2, children coordinate several systems of sensorimotor actions to form a new kind of skill – a single representation. For example, most one-year-olds have an action system for manipulating a doll and another action system for walking themselves. With the emergence of single representations late in the second year, they coordinate those two systems to form a representation in pretend play: They move the doll in a way that represents its walking across the floor. Similarly, they coordinate action systems to be able to represent actions and perceptions in speech: They say "Me walk" as they walk across the kitchen. (Single representations typically involve an agent or object doing an action or having a characteristic, such as "Me walk" and "Big cookie.")

The hypothesis of tiers led quickly to generalizations predicting later and earlier levels. We predicted that moving through levels of skills for representations, children would eventually produce another new building block, abstractions (related to what Piaget [1957] called formal operations). The tier hypothesis produced the first general model predicting the further development of new levels and capacities beyond formal operations: Starting with single abstractions, adolescents construct skills at levels of mappings, systems, and systems of systems from age 10 into adulthood (Fischer, 1980). Predictions about these levels have been strongly supported in subsequent research (Fischer, Stewart, & Yan, 2001; Kitchener, Lynch, Fischer, & Wood, 1993). Also, we predicted that in early infancy a tier of controlled reflexes leads to the emergence of sensorimotor actions at approximately four months of age (Fischer, 1980; Fischer & Hogan, 1989). Empirical evidence about these earliest levels is encouraging but not yet substantial enough to be conclusive.

Transformation Rules for Developmental Steps

A key concept for analyzing how skills are constructed is transformation rules, which both specify change processes for specific skills and define steps in developmental sequences and scales. Careful longitudinal and microdevelopmental observation of developing activities, such as search (object permanence) and pretend play, showed strongly that skills developed through sequences of many small steps in each domain. When we analyzed their skills through detailed developmental sequences, children did not usually remain for long periods at one step. Even when spurts occurred, children moved rapidly through a series of steps rather than jumping instantaneously to the next level.

How could we describe, explain, and predict these steps? What was required was a relatively continuous scale or ruler involving qualitative changes of various types and degrees. Following analogies from chemistry and geometry and building on the focus on transformations in linguistics and structuralism (Chomsky, 1957; Piaget, 1968/1970), we looked for ways that a skill could be transformed. We worked out the transformations required to explain steps in development and learning for specific developing skills, especially focusing on agency in pretend play (Watson & Fischer, 1977), self-recognition (Bertenthal & Fischer, 1978), object permanence (Bertenthal & Fischer, 1983; Corrigan, 1981; Corrigan & Fischer, 1985; Jackson, Campos, & Fischer, 1978), social roles such as mother-father, parent-child, doctor-patient, and boy-girl in stories and play (Fischer et al., 1984; Fischer & Watson, 1981; Van Parys, 1983; Watson & Fischer, 1980), and affective themes such as nice and mean in stories and interactions (Fischer & Pipp, 1984a; Fischer & Lamborn, 1989; Hand, 1982; Lamborn, 1986).

Four different rules portray most transformations of skills to create small steps within a level in a developmental sequence in a domain, and a fifth rule depicts the movement to a skill at the next level. The rules for substitution and compounding were immediately obvious in the developmental sequences that we saw: Substitution involved substituting a slightly different object or event in an activity, such as having a bear replace a doll to act in the role of mother, $\left[{BEAR \atop MOTHER} \right]$ replacing $\left[{DOLL \atop MOTHER} \right]$. Compounding involved adding a new major component, such as coordinating a child role simultaneously with mother and father roles, $\left[{WALTER \atop FATHER} \text{ — } {JANE \atop MOTHER} \text{ — } {JOHANNA \atop CHILD} \right]$, combining the simpler relationships .

The rule for shift of focus grew out of some struggles we had in distinguishing integration from mere juxtaposition of skill components. We eventually realized that it was not just a coding problem but a skill difference. This rule has turned out to be one of the most general and useful for explaining developmental transitions, occurring nearly universally in major transitions between levels that we and other investigators have studied (Fischer & Bidell, 1998; Goldin-Meadow, Nusbaum, Garber, & Church, 1993; Gottlieb, Taylor, & Ruderman, 1977). Children and adults routinely shift back and forth between two skills for doing a task, thus juxtaposing the skills, and through this process they move toward integrating them to form a new, more complex and sophisticated skill. For example, when faced with two dolls occupying the roles of mother/father (taking care of child) and wife/husband (focusing on their own relationship), three- and four-year-olds tend to confuse the roles badly, mixing up mother with wife and husband with father (Watson & Fischer, 1981; Watson & Getz, 1990). As they begin to master the distinction, they regularly shift between the role relationships rather than integrating them: $\left[{JANE \atop MOTHER} \text{ —— } {WALTER \atop FATHER} \right] > \left[{JANE \atop WIFE} \text{ —— } {WALTER \atop HUSBAND} \right]$. A few articulate children even signaled such shifts by saying sentences such as “And then a long time later they were husband and wife.”

Eventually children work through many transformations of these skills in a series of small steps until they can fully coordinate two skills at the next developmental level, which is called intercoordination, the transformation rule for full-level growth. A child can integrate, for example, mother and wife with father and husband in a single relationship, with each person occupying two roles simultaneously, $\left[\overset{\textit{WIFE}}{\underset{\textit{MOTHER}}{\textit{JANE}}} \longleftrightarrow \overset{\textit{HUSBAND}}{\underset{\textit{FATHER}}{\textit{WALTER}}} \right]$. (Interestingly, the mastery of this role distinction seems to play a key role in both children's resolution of the Oedipus conflict in nuclear families and their adaptation to their parents' breakup in divorced families (Watson & Fischer, 1993).

The final transformation rule is differentiation, which turns out to be not a separate transformation but a part of each of the other four transformations. In cognitive science, differentiation has been a hard nut to crack, with people arguing endlessly about whether differentiation precedes or follows integration (or coordination). We eventually found that the best answer is that the two are always together – two sides of the same coin, as Heinz Werner (1957) indicated. Whenever some kind of coordination occurs, such as compounding, intercoordination, and controlled shift of focus, differentiation is part of it. Likewise, any differentiation always involves a simultaneous coordination. Family roles illustrate this process. To coordinate mother with wife and father with husband, a child needs to differentiate the similar roles; and likewise to differentiate them, a child must relate them to each other by coordinating them.

Once we had carefully designed a system for assessing and analyzing the organization of activities, however, we faced two major challenges. First was how to move beyond merely asserting that *décalage* or unevenness in level is the rule in cognitive development: How can these variations be explained? Second was how to apply skill analysis to the full range of human activities – emotion, learning, context, culture, and social interaction as well as traditional cognitive tasks. Indeed, the second challenge turned out to help deal with the first one, explaining most cases of unevenness in development. The analysis of developmental variations naturally became the central task in our next decade of research.

Early Growth of the Theory: Variations in Organization and Change

The 1980s marked a major transition in the history of developmental science. While Piaget, Freud, Vygotsky, Werner, and other founders of the field still had dominant influence, various forms of "neo-theories" came to dominate the landscape, such as neo-behaviorist, neo-Piagetian, and neo-Vygotskian, along with a central emphasis on specific tasks and domains rather than grand conceptions. Many researchers were not satisfied with merely learning and using classical theories but instead aimed to work out specific applications that typically were more modest in ambition than the grand theories, such as a specific developmental analysis of use of a balance beam (Siegler, 1981) or of domain effects on self-evaluation (Harter & Pike, 1984). This emphasis on specificity fit well with skill theory's emphasis on the specificity of skills and their relative independence across domains.

In this intellectual context, skill theory entered into its second major phase of development, a fruitful period after the publication of the 1980 article. During this period we expanded our research and theory to deal with a wide range of topics, published numerous articles about this expansion, and achieved several breakthroughs in dealing with variations in the organization of action and thought and in patterns of change. Publications involved extensive empirical research (Calverley, Fischer, & Ayoub, 1994; Fischer, 1987; Fischer, Hand, & Russell, 1984; Fischer & Pipp, 1984a, 1984b; Fischer, Shaver, & Carnochan, 1989; Kitchener & Fischer, 1990) as well as advances in developmental methodology for detecting change and variation in organization (Fischer & Bullock, 1981; Fischer, Pipp, & Bullock, 1984). Four topics played an especially substantial role in development of skill theory: contextual support, social grounding, emotions and unconscious processes, and brain-growth correlates of cognitive changes.

Contextual Support: Optimal and Functional Levels

The concept of contextual support, as well as the related concepts of optimal and functional levels, initially came from our research on the development of social roles. We assessed development in two contextual-support conditions, because researchers were always arguing about whether assessments should focus on spontaneous behavior or structured, evoked behavior. When we included both conditions, we consistently found different skill levels, even in the same child in assessments just a few minutes apart in virtually identical tasks. In various explorations between 1977 and 1985 we tried to eliminate the difference between conditions through simple changes in assessment conditions, but we found that the difference robustly remained. So long as there was a difference in contextual support (little direct support versus high support), virtually all children and adults showed consistently different upper limits on their skill, even in a narrowly defined domain.

High support involved priming the gist of a task – its key components – and then asking the person to perform the task on his or her own. Low support involved simply asking for a performance on the same task without any priming. These conditions consistently produced two different, stable levels, which we named optimal and functional levels, respectively. Daniel Bullock played a key role in our eventually recognizing the basic importance of this phenomenon – the fundamental role of context in skill (Fischer & Bullock, 1984; Fischer et al., 1993; Watson & Fischer, 1980). Context directly participates as part of a skill, just as physical objects support perception through their affordances (Gibson, 1979).

In the arithmetic study we tested optimal and functional levels for the first time with evenly distributed ages, which are essential for accurately assessing the shape of a growth curve (Fischer, Hand, & Russell, 1984). Malcolm Watson's dissertation research on social roles, for example, had not distributed ages evenly (Watson & Fischer, 1980), because the experimental psychologists on his committee insisted that ages had to be clustered into narrow age groups for analysis of variance. To our surprise and delight, with distributed ages we found sharply different growth curves for high versus low support: Optimal level (high support) showed sharp discontinuities in growth at specific ages, such as jumps in skill level, while functional level (low support) showed no systematic discontinuities and commonly slow, smooth growth, as illustrated in Figure 3 for levels of development of abstract skills in adolescence and adulthood. Testing this difference in many studies across many domains, we replicated it repeatedly.

Insert Figure 3 about here.

From this work, the importance of good rulers and clocks for detecting the shapes of growth curves also emerged, because the shapes of growth curves can be detected only with decent scales and unbiased time sampling (Rose & Fischer, 1998). The finding of developmental range due to different social-contextual conditions was one of the most exciting discoveries we made because it went beyond describing *décalage* to showing a systematic basis for it in context.

The above research and thinking led to the concept of **developmental range**, one of the central concepts leading to further research on developmental variation and dynamic construction**.** *People's capacities are not fixed but vary across a broad range of levels from moment to moment*, topping out at an optimal level that appears primarily in situations with strong social-contextual support for complex understanding and acts as a dynamic attractor in skill development. Most activities occur well below that optimal level and show other kinds of limits, such as the functional level – the upper limit on skills in ordinary activity without any contextual support. It has not been an intellectually easy task, however, for researchers to appreciate the significance of the developmental range, even when they value Vygotsky's (1978) related concept of zone of proximal development. Most psychological and educational assessments give grossly inadequate portraits of people's skills because they assume one level of competence and ignore the developmental range and the several different upper limits for each person in each knowledge domain. In addition, most important processes of learning and problem-solving in children and adults take place in the variation in skill levels below optimal level (Fischer & Bidell, 1998; Fischer et al., 1993; Granott, Parziale, & Fischer, 1999).

<u>Social Grounding</u>

From the start, the goal was to find concepts and methods to analyze how behavior is fundamentally grounded in physical context and social relationships. That is why the concept of skill is foundational, and why skill level routinely varies across the developmental range and below it. That is also why we have continually studied children's and adults' constructions of social interactions and social roles, starting with Watson & Fischer (1977, 1980). The research on social-role development greatly facilitated our analyses of the social foundations of development, especially through pretend play, which powerfully combines cognition, social interaction, and emotion in one set of activities.

Children grow up in social relationships, and eventually by living in them and sharing them with the people in their lives, they come to represent the roles and interactions in play and language (Fischer et al., 1984; Fischer & Watson, 1981), as when 2-year-old Kara acts out the role of $\left[ME_{MOTHER} \right]$ and says “Kara is Mommy.” The development of self concepts and skills is grounded in the body and in relationships, as evidenced in studies with Bennett Bertenthal and Sandra Pipp (Bertenthal & Fischer, 1978; Bertenthal & Fischer, 1983; Pipp, Fischer, & Jennings, 1987; Pipp, 1990). The situations for analyzing self-recognition and self-representation skills were fundamentally interactional, with mother and interviewer being central components of the skills being assessed. The analysis of the social-contextual grounding of skills proved to be one of the most fruitful parts of skill theory, because of progress in analyzing both developmental variability and development of socioemotional relationships.

<u>Emotions and Unconscious Processes</u>

The work on social relationships relates naturally to emotions and unconscious processes, which are central parts of development and learning that we have integrated into skill theory. During the time that I was in Denver, a remarkable group of developmentalists (Joseph Campos, Susan Harter, Phillip Shaver, Robert Emde, and others) were helping to build the new functional/organizational approach to emotion and to bring emotion to the center of developmental science (Campos, Barrett, Lamb, Goldsmith, & Stenberg, 1983; Harter, 1986; Shaver, Schwartz, Kirson, & O'Connor, 1987). Working with them, we were able to formulate concepts and methods for analyzing how emotional organization participates in skill development and learning (Fischer, Shaver, & Carnochan, 1989, 1990). Children’s skills involving family relationships, for example, are obviously permeated with many powerful emotions, including love, happiness, fear, anger, and shame.

The most important concept for analyzing emotions is **action tendency** – the bias or constraint that an emotion exerts on the organization of behavior (Frijda, 1986; Lazarus, 1991). For example, the emotion of anger brings with it a strong tendency to aggressive action and speech as well as a bias to blame someone. Action tendencies thus shape skills in immediate situations, and through repeated evocation over long periods, they shape developmental pathways.

Action tendencies and other parts of the functional approach to emotion helped us to describe and analyze how emotions shape particular activities and thus developmental pathways. Three essential components for analyzing the organization of emotions are valence (positive/negative or approach/avoidance – the most pervasive dimension of emotion – as well as other fundamental dimensions such as arousal and self/other), action tendencies portrayed by emotion scripts, and grouping of emotions into conceptual families. With this synthesis of concepts of emotion into skill theory, we were able to describe many specific skill pathways that are shaped by emotions. For example, we began to describe a family of pathways for development of affective splitting and dissociation, including distinctive pathways for particular kinds of child maltreatment (Fischer & Ayoub, 1994; Fischer et al., 1997; Fischer & Pipp, 1984a). The emotion framework facilitated understanding an essential point about many pathways to psychopathology, as well as normal emotional development: Splitting and dissociation are not abnormal or pathological, but they are normal, active control processes that involve “unconscious” skills for keeping apart or dissociating broad classes of actions and thoughts shaped by emotions. In cases of extreme, abusive environments, they produce adaptations that are functional within the context of abuse but pathological outside it, as in patterns of hidden family violence and multiple personality disorder.

Brain Growth: Levels and Cycles

The discovery of developmental range, especially the distinctive growth curves for optimal level, also led to an important advance in relating brain and behavior development. We discovered that some growth curves for brain activity (electroencephalogram, abbreviated EEG) looked similar to cognitive growth curves, with shapes like the optimal level curve in Figure 3 (Fischer, 1987; Fischer & Pipp, 1984b). This discovery came from Sheldon White’s suggestion that we examine the EEG growth data of Matousek and Petersén (1973): It turns out that the ages of brain growth spurts correlate closely with the ages for emergence of each optimal level between 1 and 21 years. These similar patterns could provide a way of relating brain and behavior development by analyzing common patterns in growth curves. As a result of these findings, I was bouncing off the walls with excitement for several days.

We began consulting with developmental neuroscientists, starting with a conference on relations between brain and cognitive-emotional development, held at the University of Denver in November of 1986 and organized by Kurt Fischer and Joseph Campos with funding from the Sloan Foundation. There we first met Robert Thatcher, who collaborated with us for ten years, teaching us much about development of the brain and analysis of the EEG. His findings of growth cycles for EEG coherence and power give further evidence for straightforward relations between cognitive and cortical growth curves. In this way we began the process of describing growth cycles of brain and cognition and searching for data to pin down the patterns. Reconceptualizing stages and levels in terms of growth cycles began with the tier cycles in Figure 2, which were first proposed in 1980. In our current efforts we continue to discover ways that cycles ground development and learning (Fischer & Bidell, 1998; Fischer, Stewart, & Yan, in press).

Putting Together All the Variations

By the end of the 1980s, we had enjoyed some success in unpacking sources of variation in human development by using a set of concepts and methods for developmental levels (sequences and synchronies), developmental range, social-contextual support, emotions, and brain functioning (Fischer, 1987; Fischer & Farrar, 1987; Fischer & Hogan, 1989; Fischer & Bidell, 1991). At the same time, we obviously needed new tools for analyzing the connections among the parts of human development.

One problem that illustrates this need is the **generalization** of skills: How can the range of generalization be analyzed and predicted? People often generalize skills from one task or situation to another, but predicting when generalization occurs has proved to be one of the most difficult problems in cognitive science. For example, 12-year-old adolescent Johanna comes to understand that her best friend feels neglected when Johanna forgets about her birthday, but her best friend is only one of the people she is close to. Predicting whether and when she will generalize that understanding to, say, her mother’s birthday is difficult. Much research finds little evidence for generalization of classroom instruction, even from courses designed to teach generalizable knowledge (Detterman, 1993; Perkins & Salomon, 1989). Analysis of development provides a powerful window for understanding, predicting, and producing transfer, and the skill theory research of the late 1980s began this analysis: We are able (a) to predict sequences of generalization within a domain, (b) to separate generalization from concurrent development of distinct skills, and (c) to specify pathways of generalization driven by emotional experiences.

At the same time, skill theory could not predict and explain the full range of generalization across task domains in individual people. For instance, degrees of contextual support strongly affect range of generalization within a task domain, but predicting variations in individual generalization with support can be done only by combining multiple factors in a single model, not merely acknowledging their relevance. Research in the 1980s and beyond continued to show that skill theory tools can be used successfully to analyze specific patterns of skill organization and change, but dealing comprehensively with the pervasive variations in behavioral organization requires the use of dynamic systems concepts and mathematical models of growth.

Later Growth of the Theory: Dynamics of Variation

The last decade has seen rapidly growing attempts to apply dynamic systems theory to human development and other parts of psychology (Bogartz, 1994; Case & Okamoto, 1996; Fischer et al., 1993; Fischer & Hogan, 1989; Port & van Gelder, 1995; Thelen & Smith, 1994; Vallacher & Nowak, 1994; van der Maas & Molenar, 1992; van Geert, 1991). The common theme underlying all these efforts is analysis of the ways that many factors interact complexly over time in context to produce wide variation in action, thought, and development. Modern dynamic systems theory provides important tools for analyzing and understanding the complex organization and variation in real-life human development.

Although dynamic systems theory is deeply rooted in the systems theory of the 1950s and 1960s (von Bertalanffy, 1968), it goes well beyond those general, sometimes vague concepts to offer powerful analytic tools. Specific concepts such as self-organization, emergence, complexity, nonlinearity, attractor, and fractal combine with explicit mathematically sophisticated tools for analyzing and explaining complex variations, and they have been widely used in physics, biology, and industry (Forrester, 1961; Huckfeldt, Kohfeld, & Likens, 1982; Levine & Fitzgerald, 1992; Prigogine & Stengers, 1984; Zeeman, 1976). Piaget's (1975/1985) concept of equilibration is also relevant – how growth processes work together to produce relatively stable, long-term skills and knowledge built on activities (van Geert, 1998).

Skill theory concepts obviously demand dynamic analysis of development and learning, and dynamic systems theory provides not only an emphasis on analysis of variation but also powerful analytic tools and a focus on complex growth patterns such as that for optimal level in Figure 3. The dynamic systems perspective helps bring together the system for analyzing change in skill organization created in the 1970s with the many components studied in the 1980s that produce complex variations in action, thought, and emotion across domains. Following our collective nose, we found a remarkable match between skill theory and dynamic systems theory.

<u>Modeling Dynamics in Competence</u>

The banner year for this effort was 1992, when we formed a study group at the Center for Advanced Study in the Behavioral Sciences at Stanford to work together on applying dynamic systems theory to analysis of development. The core members of this group were developmental psychologists Kurt Fischer, Robbie Case, and Paul van Geert, with support from neuroscientist Robert Thatcher, developmentalists Katherine Nelson, Peter Molenaar, and Han van der Mass, cognitive scientist Nira Granott, statistician John Willett, and social psychologist Abraham Tesser. For the entire year we worked intensively to devise tools for modeling and measuring dynamic growth and development, including a series of specific mathematical models (Case & Okamoto, 1996; Fischer & van Geert, 1993; Fischer & Kennedy, 1997).

This study group had a profound impact on the development of what we now call **dynamic skill theory**. We learned how well the dynamic systems perspective complements skill theory concepts and methods. Melding the two produces a powerful framework, with blueprints and a toolkit for analyzing change and variation in the organization of actions, thoughts, and feelings in individuals and small groups, which we call ensembles (Fischer & Granott, 1995). We are engaged in building models for processes of growth and change and capturing important pathways of development and learning.

The first major product of our research along this line was a book chapter entitled “The Dynamics of Competence: How Context Contributes Directly to Skill” (Fischer et al., 1993), which was the first publication of ours that included the word “dynamics” in the title. Criticizing the traditional concept of fixed competence, we explained how immediate context contributes directly to skill level as evidenced in optimal and functional levels. Most important, we synthesized the many findings about developmental range and systematically explained the dynamic processes underlying development, including a sketch of a neural-network model. People act *in medias res* – in the middle of things in the real world, not merely as logical agents acting on objects rationally and without emotion.

Contrary to static conceptions, *people have no single fixed competence like the capacity of a drinking glass, but instead there is a dynamic range of competences.* People’s activities vary widely from moment to moment up and down a developmental complexity scale (defined by skill levels) as a function of degree of contextual support, emotional match, and specific task demands of the moment. When contextual support changes, a person’s level changes. The upper limit on performance (the competence) varies directly with support. Both human behavior and models of neural networks show this dynamic variation as a function of support. This was the beginning of our most successful dynamic analysis until that date and led to mathematical models of developmental range as a function of contextual support, task, domain, and experience with a situation (Fischer & Kennedy, 1997).

Context powerfully organizes development in many ways, and variation in support is only one part of context’s effects. Differences in task and domain also powerfully shape developmental pathways. A useful model for such contextual factors, first formulated by Thomas Bidell, is the construction of a web, illustrated in Figure 4 (Bidell & Fischer, 1992). This metaphor has generated a number of useful analytic tools and concepts for describing developmental pathways, including their multiple, partly independent strands (Fischer & Bidell, 1998; Fischer, Stewart, & Yan, in press). The web highlights the separation of diverse domains (strands), the joining and dividing that can occur within a domain (along a strand), and the concurrent zone for discontinuous changes across many strands – all seen in Figure 4. Distinct strands represent separate task domains, and the general separation of strands on the left and right reflect the encapsulation or dissociation of skill domains, such as private roles versus public roles, or spatial reasoning versus verbal reasoning. The box in Figure 4 indicates the concurrent zone for the emergence of an optimal level, marked by a cluster of discontinuities (spurts, drops, junctions, and forks).

Insert Figure 4 here.

Microdevelopment

The dynamic framework affirms the importance of microdevelopment, short-term patterns of change based on processes of learning and development. Dynamic analysis emphasizes both processes of change and the importance of analyzing the specifics of growth in individual people instead of through group means. Because growth is frequently nonlinear, group data can only be used when careful assessments are made to ensure that group means actually represent individual growth patterns. The themes of change processes and individual growth were both present in skill theory from the start, but the dynamic framework shows how central they are to the enterprise of understanding skill variation and change.

Skill theory actually began with microdevelopmental analysis, which was the topic of Kurt Fischer's thesis on learning in individual rats and pigeons in 1970. Our goal was to find a common framework for integrating microdevelopment with long-term growth (macrodevelopment), but many years of work on macrodevelopment intervened before Thomas Bidell and Nira Granott in the early 1990s led us to breakthroughs in concepts and methods for analyzing microdevelopment (e.g., Bidell & Fischer, 1994; Fischer & Granott, 1995). The short-term developmental changes found in these studies vividly demonstrated the dynamic nature of microdevelopment and the relation with macrodevelopment. Microdevelopmental studies have now become a critical resource for uncovering and explaining growth mechanisms underlying developmental variations, and they also provide ways to test dynamic skill ideas in everyday activities relating to learning and education.

When children or adults are faced with a task or problem they cannot immediately solve, such as working with a Lego robot or building a friendship with a new peer, they routinely lower their activities with the task down to a low level, as illustrated in Figure 5, and they rebuild their skills to fit the new task. They explore the task with simple activities that help them build a more adequate representation of the specifics of the task. This process is not a unitary march toward higher level skill but involves frequent drops to a low level to build and rebuild the skill, as shown in Figure 5 (Granott, 1994; Granott, in press; Granott, Fischer, & Parziale, in press; Yan, 2000). Animals learn through a process similar to people (Fischer 1980a). In novel tasks, many rebuildings are required to achieve generalizable skill. Importantly, this constructive process is typically done in collaboration with peers or mentors, forming ensembles for learning and problem-solving (Granott, 1993).

Insert Figure 5 about here.

An important microdevelopmental finding is that most tasks, even in educational settings, do not require people's optimal skill levels but can be effectively done at lower levels. In our microdevelopmental research to date, people seldom approach their optimal or functional levels, even when they show expert performance. When faced with a task, experts initially drop down to a lower level only briefly and then move up to the level required for adequate performance of the task, where typically their performance remains mostly steady. Novices, on the other hand, show highly variable skill levels, building and rebuilding the skill many times in order to move to a high-enough, stable level of performance (Fischer, Yan, McGonigle, & Warnett, 2000; Yan, 2000). In this ongoing research, we seek to understand dynamic patterns and mechanisms of growth and variation and to build explicit dynamic models of these changes.

Diverse Developmental Pathways, Emotions, and Interactions

Emotions and close relationships (are major contributors to the dynamics of growth and variation and primary influences in shaping pathways for both macrodevelopment and microdevelopment. Indeed, emotions *in* close relationships have especially powerful effects. Research has led to discovery of many different pathways and to questioning of traditional analyses that assume one common pathway for most people. The tools for skill analysis make it possible to analyze individual developmental pathways from a person's own viewpoint instead of forcing him or her to act in terms of the viewpoint embodied in a standard model of development, such as science and logic (Piaget, 1970a), ego maturity (Loevinger, 1976), healthy interpersonal skills (Ainsworth, Blehar, Waters, & Wall, 1978; Kohut, 1971), or moral judgment (Kohlberg, 1984).

One common belief among behavioral scientists is that psychopathology involves retarded, fixated, or regressed development: People with narcissistic disorders, schizophrenia, autism, and many other disorders are said to be stuck at an early point along the normative developmental ladder to mental health. Our research challenges this belief. In research with abused children, adolescents, and adults, for example, individuals developed to the normative optimal level for their age when assessed from their own perspective. They showed an *idiosyncratic emotional organization of relationships*, but their skill level was not retarded, fixated, or regressed.

Many abused adolescents in our studies organize themselves in their relationships around the assumption that they are fundamentally bad, in contrast to the usual positive self-bias that accompanies most healthy development. With methods that can detect this distinctive self-organization, these adolescents show levels of skill complexity that are entirely normal for their age, with no developmentally primitive skills. From the dynamic skill perspective, most psychopathology involves distinctive developmental pathways, not primitive ones (Calverley et al., 1994; Fischer, Ayoub, Noam, Singh, Maraganore, & Raya, 1997). Dynamic skill theory provides tools for detecting and analyzing these distinctive pathways.

Both macro- and microdevelopment work mostly through social interactions, especially in close relationships. People interact and develop together in ensembles, not acting in isolation. Even when people act alone, their activities are grounded in close relationships and social supports. Skill theory tools work well in analyzing these growth processes, combining cognitive, contextual, social, and emotional factors. Nira Granott has shown how adult students spontaneously form small ensembles (dyads or triads) to solve new problems together, often working effectively as an integrated social unit that cannot easily be divided into separate individuals for analysis. Michael Mascolo has analyzed how mother and child play with a toy together to build skills as well as relationship, as well as how adult couples act together in therapy to elaborate and hopefully mend difficulties in their relationships (Mascolo & Fischer, 1998; Mascolo, Fischer, & Neimeyer, 1999; see also Westerman, 1990) . We expect this new direction to become increasingly important in dynamic skill theory – unpacking the socioemotional roots of micro- and macrodevelopment as well as the cultural construction of emotions and relationships (Mascolo, Fischer, & Li, in press; Fischer, Wang, Kennedy, & Cheng, 1998).

Synthesis of Many Components in Skill Theory

The greatest challenge of dynamic skill analysis is the same as the greatest challenge of analyzing human behavior: combining the many components in a way that (a) unpacks without dissecting and (b) simplifies and clarifies enough to help understanding rather than overwhelming it. In the chapter by Fischer and Bidell (1998) in the Handbook of Child Psychology, we present an overview of the dynamic structural approach to development that aims to present a number of concepts, tools, and applications coherently and clearly. Moving beyond the previous frameworks of skill theory, this new synthesis has several important features that articulate key components of skill theory with dynamic systems:

1. It is a **grounded theory** of development, interweaving concepts with methods for analyzing dynamic structures and requiring explication in terms of specific activities in context. Research designs, measurement tools, and data analysis techniques are all intertwined with the theoretical framework.
2. It moves beyond neo-Piagetian structuralism to **dynamic constructivism**, in which skill organizations vary dynamically according to specifiable growth processes and control parameters. Different from most dynamic systems approaches, such as Thelen and Smith (1994), dynamic skill theory begins its analysis with a wide variety of **developmental** changes in children's and adolescents' specific activities. Different from most neo-Piagetian approaches, such as Case (1991, Case & Okamoto, 1996) and Piaget (1983), it deals with development and **variation in real-life activities**, not focusing on logic, rationality, or unitary competence. It integrates analysis of growth processes with the dynamics of actions and tasks rather than focusing primarily on just tasks or just rational development.

3. Developmental **variation**, as in developmental range, microdevelopment, and pathways, are taken as critical resources for grounding developmental analysis rather than as random noise or measurement error.
4. Dynamical **concepts** are brought to the foreground, such as stability within variation, *in medias res*, collaborative construction, constructive web, growth and transition processes, dynamic growth modeling, the organizing effects of emotions, and cycles of reorganization in the developing brain.

Over 30 years of development, dynamic skill theory has gradually taken its current shape. Still we are at the beginning of the intellectual journey of understanding human development in all its richness and diversity. Our new challenge is how to understand the broad spectrum of human development across different domains and through various levels. The newly established Mind, Brain, and Education program at the Harvard Graduate School of Education represents our latest effort to bring a multidisciplinary perspective to the enterprise. To understand the rich diversity of human development requires contributions from a wide range of disciplines, integrating cognitive science, neuroscience, anthropology, pedagogy, philosophy, linguistics, and many other disciplines.

Dynamic Construction of Dynamic Skill Theory

Like the development of a child, dynamic skill theory was constructed dynamically over time, with multiple factors interacting within a coherent system in context to produce change and variation. The previous sections of this chapter have focused primarily on the concepts and methods of dynamic skill theory. To capture the dynamic construction process, we also describe development of the theory in terms of four metaphors based on acting with one's body: following our noses, opening our eyes, moving our legs, and holding each other's hands.

Following Our Noses

During our 30-year journey of developing the theory, we repeatedly followed our noses: We pointed ourselves in a general direction and then groped forward, letting observations and interactions guide us toward a solution. We started with a strong, general sense of where we wanted to go – most broadly, understanding how people change in a wide and rich panoply of ways – but we did not know how to get there. Baldwin (1894) and Piaget (1936/1952) described this process of **groping** in child development, and it applies as well to scientific discovery. Good science relies primarily neither on deduction according to logical principles, nor on naked induction from observations, but on a construction that dynamically combines direction from both the scientist and the world observed. This is the process that the great 19th-century philosopher C. S. Peirce (1982-1993) called "abduction" (Hanson, 1961).

Early in the dynamic construction of skill theory, we had to follow our noses to build a system for analyzing change in the organization of action and thought. Grounded in concepts from Piaget, Bruner, Werner, and others, we explored ways of characterizing the development of specific activities in infants and children and gradually invented the system that was presented in the 1980 *Psychological Review* paper. Later when we were challenged by pervasive and complex variations in the organization of actions, thoughts, and feelings, we followed our noses again to find concepts and methods for analyzing the dynamics of variations. Key in all the successes of the 30-year journey was the emergent process of groping and dynamic construction to produce concepts and methods grounded in people's developing activities and not fixed by one pre-determined theory or method.

<u>Opening Our Eyes</u>

As we groped forward following our noses, it was essential to keep our eyes open, consistently finding and integrating new observations, insights, and tools into the existing framework so that we could better understand developmental processes. To achieve any success in the challenging task of understanding human development requires going beyond the one-dimensional theories that still dominate most of the developmental, educational, and cognitive sciences. We needed to stay open to seeing what developing children and adults showed us, and we needed to continually reach out to explore new ideas and methods from any relevant disciplines. Skill theory was invented in the 1970s and 1980s from concepts, findings, and methods involving cognitive development, learning, problem-solving, emotions, psychopathology, cultural similarities and differences, social relationships, ecological analysis, and other phenomena. Dynamic skill theory was formulated in the 1990s on the basis of concepts, findings, and methods involving change in dynamic systems, variations across and within cultures, attachment patterns, microdevelopmental analyses, neural networks, brain growth, biological growth cycles, and neuroscience. Openness to different ideas, observations, and methods made possible the long dynamic journey toward understanding human development in all its richness and diversity.

Moving Our Two Legs

So much work in the behavioral sciences focuses primarily on either theory or method, not on the connection of the two. To walk effectively, people need two legs. To do the best work, scientists need the two legs of theory and method together. Our research experience tells us that it is neither sufficient nor wise to rely mainly on one leg or the other to advance the study of human development. During our 30-year journey of following our noses with open eyes, we have strove consistently to use both legs, matching and integrating both conceptual improvements and methodological advances in order to build the best explanations of developing actions, thoughts, and feelings. Along with essential concepts such as skill, developmental range, and dynamic growth, we have tried always to find or devise appropriate methods, such as task analysis, optimal and functional assessment, and dynamic modeling, respectively. Theory and method have been so closely intertwined in our research that every major advance has involved a combination of concept and method together to produce a more effective analytic system.

Holding Each Other's Hands

The enterprise of building dynamic skill theory never involved one person. There was always a group of us walking forward with our eyes open following our noses, intensively and successfully collaborating in our journey. Despite American culture's emphasis on individual achievements, one person alone cannot capture the richness and diversity of human development. Scientific research by nature is a social construction process (Ochs & Jacoby, 1997).

We have had good fortune to work closely with three major groups of collaborators. First, formulation of skill theory has been significantly influenced by our mentors, including those we worked with personally and those we knew only through their writings, especially Piaget, Skinner, Freud, Bruner, Roger Brown, Fantino, Hebb, Kagan, Kohlberg, Harry Stack Sullivan, Vygotsky, Werner, and Sheldon White. Second, collaborations with colleagues have been essential to our progress, especially Joseph Campos, Robbie Case, Paul van Geert, Marshall Haith, Susan Harter, Karen Kitchener, Gil Noam, Phillip Shaver, and Robert Thatcher. Third, we have had the remarkable good fortune to work with a group of bright and diligent graduate students, some of whom have gone on to become colleagues and collaborators for many years. We learn from each other, inspire each other, and support each other! Students who have become long-term collaborators have included Catherine Ayoub, Thomas Bidell, Daniel Bullock, Roberta Corrigan, Nira Granott, Rebecca Hencke, Catherine Knight, Jin Li, Michael Mascolo, and Samuel Rose, and Malcolm Watson.

In short, during our 30 years of research, we have been following our noses in active exploration, opening our eyes for constructive synthesis of new insights, moving our two legs of theory and method together, and holding each other's hands for long-term collaboration. The sweet fruit of our constructive collaboration has been dynamic skill theory. Time will tell how dynamic skill theory fares as it moves from its childhood into the adulthood we seek in the new millennium. Most important, we hope that dynamic skill theory will continue to help us human beings better understand how we develop in all our richness and diversity.

List of Figures and Tables

Figure 1. Spurt in Personal Pronoun Use Marking a New Optimal Level: Tomas

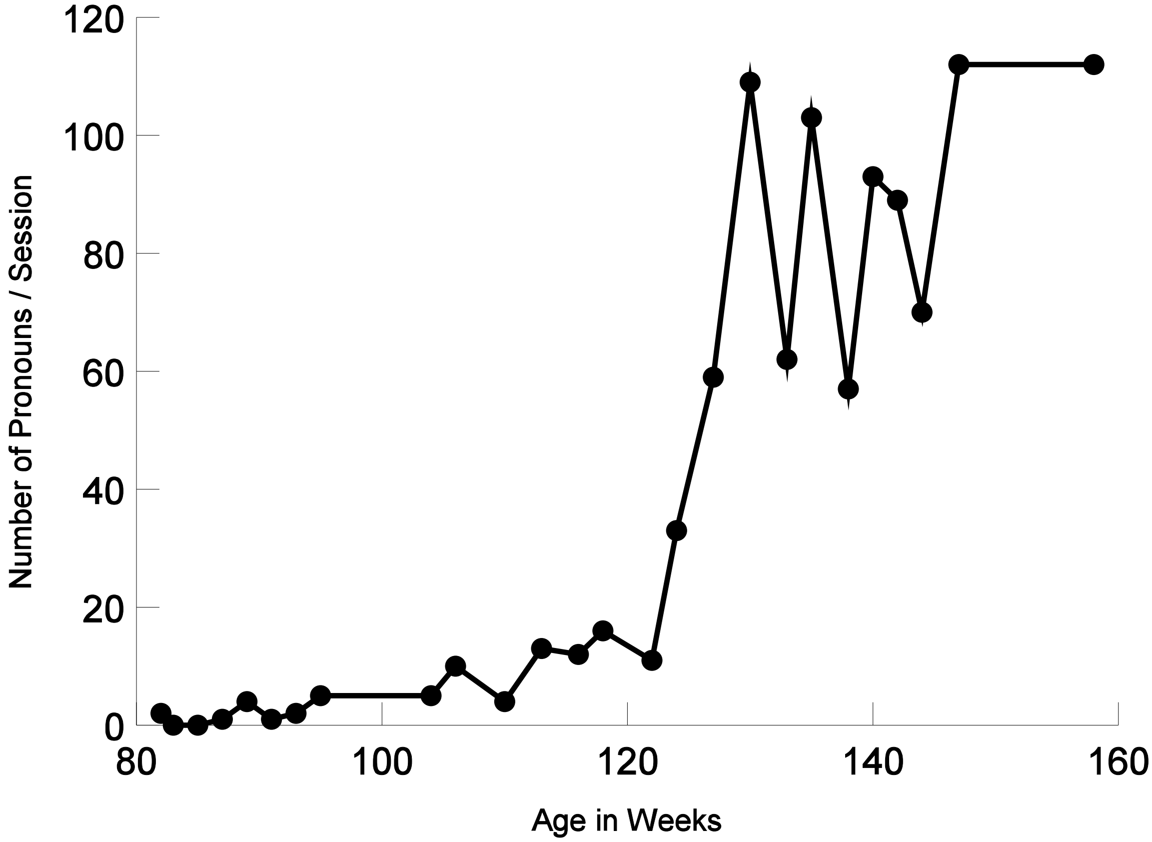


Figure 2. Cycle of Levels and Tiers

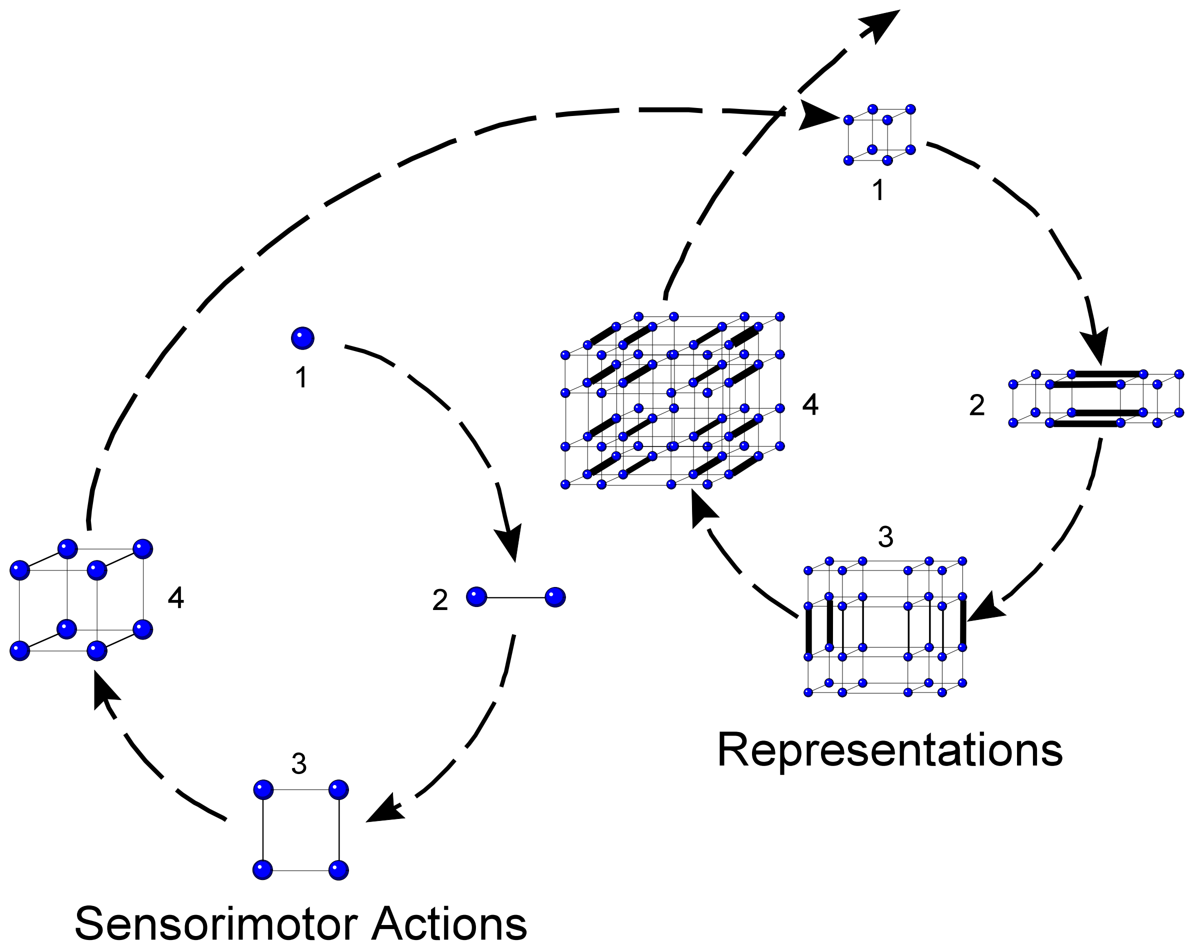


Figure 3. Optimal and Functional Levels for Abstract Skills

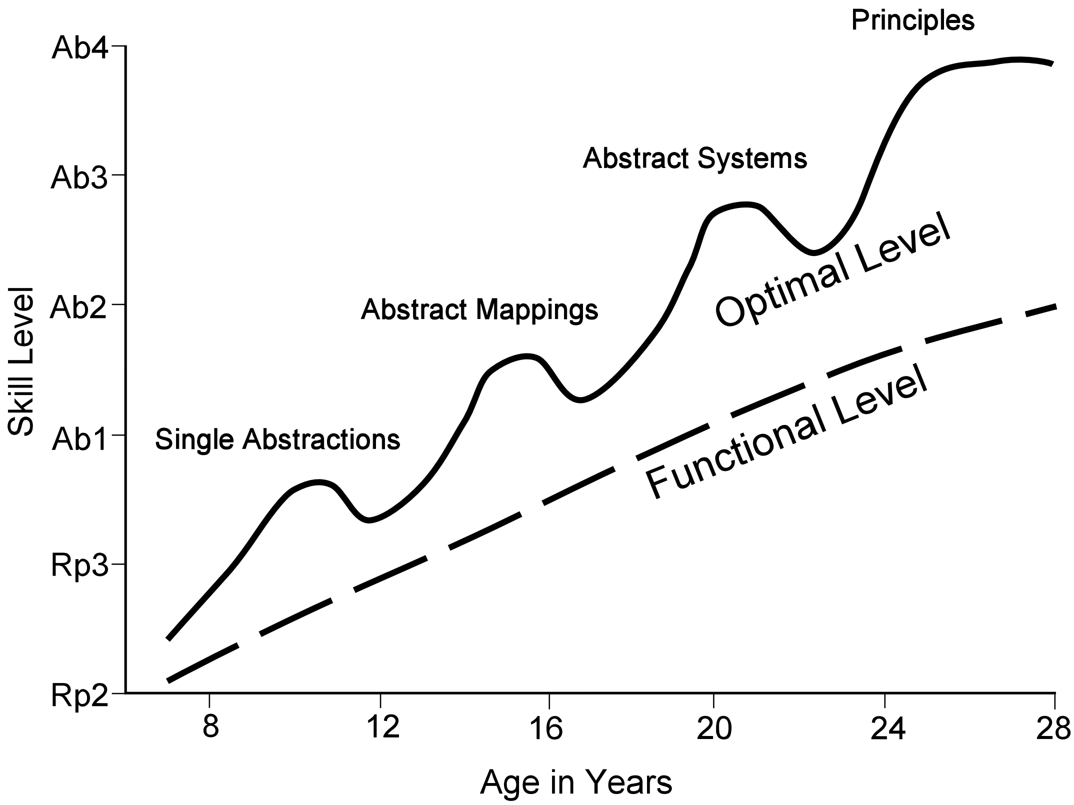


Figure 4.
Constructed Web of Development: Parallel, Distributed Strands and Concurrent Zone

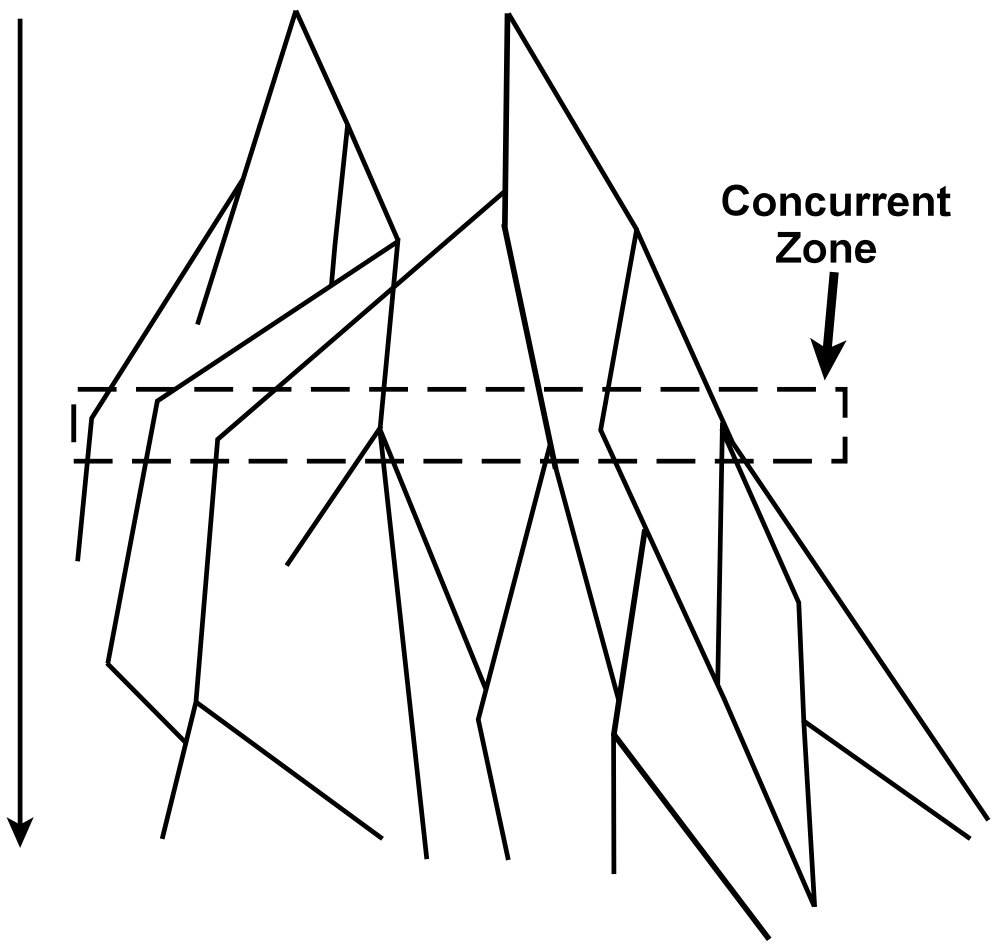
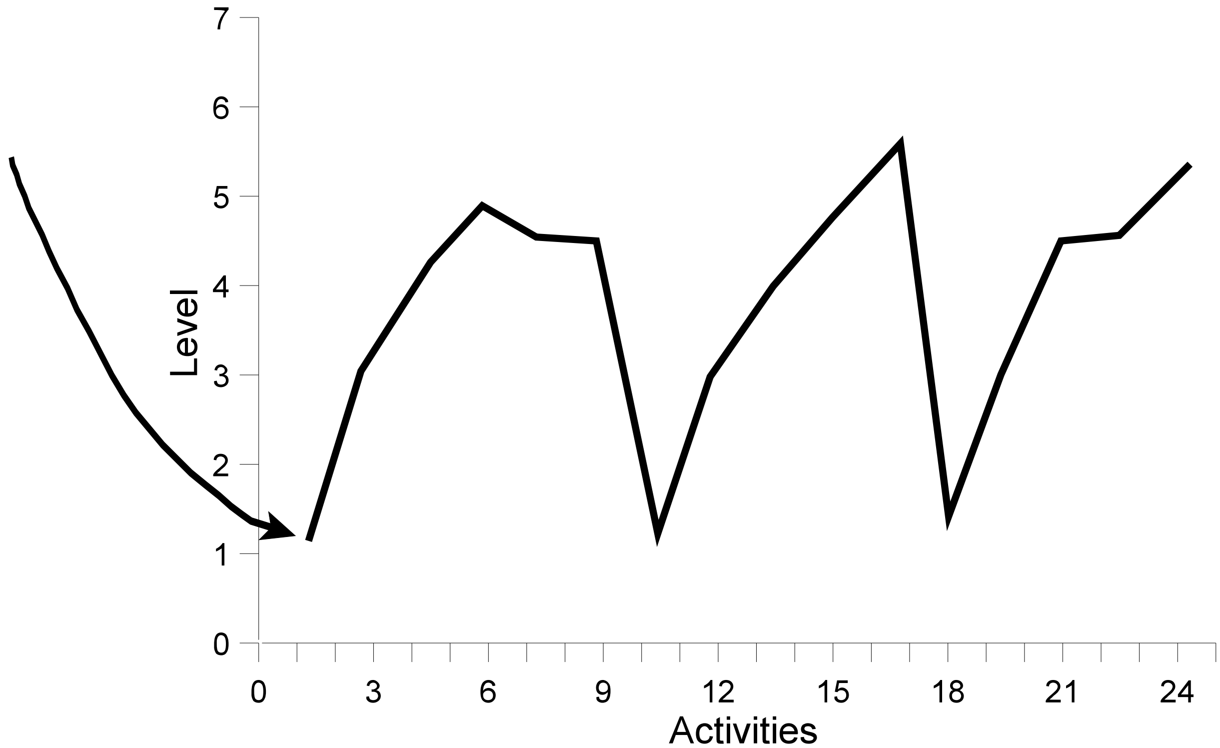


Figure 5. Backward Transition to Build & Rebuild a New Skill



References

Ainsworth, M. D., Blehar, M., Waters, E., & Wall, S. (1978). Patterns of attachment: A psychological study of the strange situation. Hillsdale, N.J.: Erlbaum.

Baldwin, J. M. (1894). Mental development in the child and the race. New York: MacMillan.

Bertenthal, B. I., & Fischer, K. W. (1978). The development of self-recognition in infancy. Developmental Psychology, 14, 44-50.

Bertenthal, B. I., & Fischer, K. W. (1983). The development of representation in search: A social-cognitive analysis. Child Development, 54(4), 846-857.

Bidell, T. R., & Fischer, K. W. (1992). Cognitive development in educational contexts: Implications of skill theory. In A. Demetriou, M. Shayer, & A. Efklides (Eds.), Neo-Piagetian theories of cognitive development: Implications and applications for education (pp. 9-30). London: Routledge & Kegan Paul.

Bidell, T.R., & Fischer, K.W. (1994). Developmental transitions in children's early on_line planning. In M. M. Haith, J. B. Benson, R. J. Roberts Jr., & B. F. Pennington (Ed.), The development of future_oriented processes (pp. 141-176). Chicago: University of Chicago Press.

Bogartz, R. (1994). The future of dynamic systems models in developmental psychology in the light of the past. Journal of Experimental Child Psychology, 58, 289-319.

Bruner, J. S. (1970). The growth and structure of skill. In K. J. Connolly (Ed.), Mechanisms of motor skill development New York: Academic Press.

Bruner, J. S. (1973). Organization of early skilled action. Child Development, 44, 1-11.

Calverley, R., Fischer, K.W., & Ayoub, C. (1994). Complex splitting of self-representations in sexually abused adolescent girls. Development and Psychopathology, 6, 195-213.

Campos, J. J., Barrett, K. C., Lamb, M. E., Goldsmith, H. H., & Stenberg, C. (1983). Socioemotional development. In M. M. Haith & J. J. Campos (Eds.), & P. H. Mussen (Series Ed.), Handbook of child psychology: Vol. 2. Infancy and developmental psychobiology (4th ed., pp. 783-915). New York: Wiley.

Case, R. (Ed.) (1991). The mind's staircase: Exploring the conceptual underpinnings of children's thought and knowledge. Hillsdale: Erlbaum.

Case, R., & Okamoto, Y. (1996). The role of central conceptual structures in the development of children's thought. Monographs of the Society of Research in Child Development, 61. Chicago, IL: Society for Research in Child Development.

Chomsky, N. (1957). Syntactic structures. The Hague: Mouton.

Corrigan, R. (1981). The effects of task and practice on search for invisibly displaced objects. Developmental Review, 1, 1-17.

Corrigan, R. (1983). The development of representational skills. In K. W. Fischer (Ed.), Levels and transitions in children's development. New Directions for Child Development, 21, 51-64. San Francisco: Jossey-Bass.

Corrigan, R., & Fischer, K. W. (1985). Controlling sources of variation in search tasks: A skill theory approach. In H. Wellman (Ed.), Children's searching: The development of search skill and spatial representation (pp. 287-318). Hillsdale, N.J.: Erlbaum.

Damon,W. (Ed.). (1998). Handbook of child psychology. New York: Wiley.

Detterman, D. K. (1993). The case for the prosecution: Transfer as an epiphenomenon. In D. K. Detterman & R. J. Sternberg (Eds.), Transfer on trial: intelligence, cognition, and instruction (pp. 1-24). Norwood, N.J.: Ablex.

Fischer, K.W. (1970). The structure and development of sensory_motor actions. Ph.D. dissertation, Harvard University, Department of Social Relations, August, 1970.

Fischer, K.W. (1972). Structuralism for psychologists: A review of An introduction to structuralism (Basic Books, 1970), by Michael Lane. Contemporary Psychology, 17, 329_331.

Fischer, K. W. (1975). Thinking and problem solving: Cognitive psychology. In K. W. Fischer, P. R. Shaver, & A. Lazerson (Eds.), Psychology today: An Introduction (3rd ed., pp. 120-143). New York: CRM/Random House.

Fischer, K.W. (1980a). Learning and problem solving as the development of organized behavior. Journal of Structural Learning, 6, 253_267.

Fischer, K.W. (1980b). A theory of cognitive development: The control and construction of hierarchies of skills. Psychological Review, 87, 477_531.

Fischer, K.W. (1987). Relations between brain and cognitive development. Child Development, 58, 623-632.

Fischer, K. W., & Ayoub, C. (1994). Affective splitting and dissociation in normal and maltreated children: Developmental pathways for self in relationships. In D. Cicchetti & S. L. Toth (Eds.), Rochester Symposium on Developmental Psychopathology: Vol. 5. Disorders and dysfunctions of the self (pp. 149-222). Rochester, N.Y.: Rochester University Press.

Fischer, K. W., Ayoub, C. C., Noam, G. G., Singh, I., Maraganore, A., & Raya, P. (1997). Psychopathology as adaptive development along distinctive pathways. Development and Psychopathology, 9, 751-781.

Fischer, K.W., & Bidell, T.R. (1991). Constraining nativist inferences about cognitive capacities. In S. Carey & R. Gelman (Eds.), The epigenesis of mind: Essays on biology and knowledge. Hillsdale, NJ: Erlbaum. Pp. 199-235.

Fischer, K. W., & Bidell, T. R. (1998). Dynamic development of psychological structures in action and thought. In R. M. Lerner (Ed.), & W. Damon (Series Ed.), Handbook of child psychology: Vol. 1. Theoretical models of human development (5th ed., pp. 467-561). New York: Wiley.

Fischer, K. W., & Bullock, D. (1981). Patterns of data: Sequence, synchrony, and constraint in cognitive development. In K. W. Fischer (Ed.), Cognitive development. New Directions for Child Development, 12, 69-78. San Francisco: Jossey-Bass.

Fischer, K.W., & Bullock, D. (1984). Cognitive development in middle childhood: Conclusions and new directions. In W.A. Collins (Ed.), Development during middle childhood: The years from six to twelve (pp. 70-146). Washington, D.C.: National Academy of Sciences Press.

Fischer, K.W., Bullock, D., Rotenberg, E.J., & Raya, P. (1993). The dynamics of competence: How context contributes directly to skill. In R. Wozniak & K.W. Fischer (Eds.), Development in context: Acting and thinking in specific environments (pp. 93-117). JPS Series on Knowledge and Development. Hillsdale, N.J.: Erlbaum.

Fischer, K.W., & Farrar, J. (1987). Generalizations about generalization: How a theory of skill development explains both generality and specificity. International Journal of Psychology, 22, 643-677.

Fischer, K. W., & Granott, N. (1995). Beyond one-dimensional change: Parallel, concurrent, socially distributed processes in learning and development. Human Development, 38, 302-314.

Fischer, K.W., Hand, H.H., & Russell, S. (1984). The development of abstractions in adolescence and adulthood. In M. Commons, F.A. Richards, and C. Armon (Eds.), Beyond formal operations (pp. 43-73). New York: Praeger.

Fischer, K. W., Hand, H. H., Watson, M. W., Van Parys, M., & Tucker, J. (1984). Putting the child into socialization: The development of social categories in preschool children. In L. Katz (Ed.) Current topics in early childhood education (Vol. 5, pp. 27-72). Norwood N.J.: Ablex.

Fischer, K. W., & Hogan, A. E. (1989). The big picture for infant development: Levels and variations. In J. J. Lockman & N. L. Hazen (Eds.), Action in social context: Perspectives on early development (pp. 275-305). New York: Plenum Press.

Fischer, K. W., & Kennedy, B. (1997). Tools for analyzing the many shapes of development: The case of self-in-relationships in Korea. In E. Amsel & K. A. Renninger (Eds.), Change and development: Issues of theory, method, and application (pp. 117-152). Mahwah, N.J.: Erlbaum.

Fischer, K. W., & Lamborn, S. (1989). Mechanisms of variation in developmental levels: Cognitive and emotional transitions during adolescence. In A. de Ribaupierre (Ed.), Transition mechanisms in child development (pp. 33-67). New York: Cambridge University Press.

Fischer, K.W., & Pipp, S.L. (1984a). Development of the structures of unconscious thought. In K. Bowers & D. Meichenbaum (Eds.), The unconscious reconsidered (pp. 88-148). New York: Wiley.

Fischer, K.W., & Pipp, S.L. (1984b). Processes of cognitive development: Optimal level and skill acquisition. In R.J. Steinberg (Ed.), Mechanisms of cognitive development (pp. 45-80). San Francisco: Freeman.

Fischer, K.W., Pipp, S.L., & Bullock, D. (1984). Detecting discontinuities in development: Method and measurement. In R. Emde & R. Harmon (Eds.), Continuities and discontinuities in development (pp. 95-121). New York: Plenum.

Fischer, K.W., Shaver, P., & Carnochan, P. (1989). A skill approach to emotional development: From basic- to subordinate-category emotions. In W. Damon (Ed.), Child development today and tomorrow (pp. 107-136). San Francisco: Jossey-Bass.

Fischer, K. W., Shaver, P. R., & Carnochan, P. (1990). How emotions develop and how they organise development. Cognition & Emotion, 4(2), 81-127.

Fischer, K. W., Yan, Z., & Stewart, J. (in press). Cognitive development in adulthood: Dynamics of variation and consolidation. In J. Valsiner & K. Connolly (Eds.), Handbook of developmental psychology. Thousand Oaks, CA: Sage.

Fischer, K.W., & van Geert, P. (1993). Modeling and measuring growth and development: Excerpts from the Group Report. Center for Advanced Study in the Behavioral Sciences: Annual Report 1993 (pp. 39-44). Palo Alto, CA.

Fischer, K. W., Wang, L., Kennedy, B., & Cheng, C. (1998). Culture and biology in emotional development. In D. Sharma & K. W. Fischer (Ed.), Socioemotional development across cultures. New Directions for Child Development, 81, 21-43. San Francisco: Jossey-Bass.

Fischer, K. W., & Watson, M. W. (1981). Explaining the Oedipus conflict. In K. W. Fischer (Ed.), Cognitive development. New Directions for Child Development, 12, 79-92. San Francisco: Jossey-Bass.

Fischer, K. W., Yan, Z., McGonigle, B., & Warnett, L. (2000). Learning and developing together: Dynamic construction of human and robot knowledge. In J. Weng & I. Stockman (Eds.), Workshop on Development and learning: Proceedings of an NSF/DARPA workshop (pp. xxx-xxx). East Lansing, MI: Michigan State University.

Fogel, A. (1993). Developing through relationships: Origins of communication, self, and culture. Chicago: University of Chicago Press.

Forrester, J. W. (1961). Industrial dynamics. Cambridge, MA: MIT Press.

Frijda, N. H. (1986). The emotions. Cambridge, England: Cambridge University Press.

Frye, D., Zelazo, P. D., & Palfai, T. (1995). Theory of mind and rule-based reasoning. Cognitive Development, 10, 483-527.

Gibson, J. J. (1979). The ecological approach to visual perception. Boston: Houghton-Mifflin.

Goldin-Meadow, S., Nusbaum, H., Garber, P., & Church, R. B. (1993). Transitions in learning: Evidence for simultaneously activated rules. Journal of Experimental Psychology: Human Perception and Performance, 19, 92-107.

Gottlieb, D. E., Taylor, S. E., & Ruderman, A. (1977). Cognitive bases of children's moral judgments. Developmental Psychology, 13, 547-556.

Granott, N. (1994). Microdevelopment of co-construction of knowledge during problem-solving: Puzzled minds, weird creatures, and wuggles. Dissertation Abstracts International, 54(10B), 5409.

Granott, N. (in press). How microdevelopment creates macrodevelopment: Reiterated sequences, backward transitions, and the zone of current development. In N. Granott & J. Parziale (Eds.), Microdevelopment: Transition processes in development and learning Cambridge, U.K.: Cambridge University Press.

Granott, N. (1993). Patterns of interaction in the co-construction of knowledge: Separate minds, joint effort, and weird creatures. In R. H. Wozniak & K. W. Fischer (Eds.), Development in context: Acting and thinking in specific environments (pp. 183-207). Hillsdale, N.J.: Erlbaum.

Granott, N., Fischer, K. W., & Parziale, J. (2002). Bridging to the unknown: A transition mechanism in learning and problem-solving. In N. Granott & J. Parziale (Eds.), Microdevelopment: Transition processes in development and learning (pp. 131-156). Cambridge, U.K.: Cambridge University Press.

Hand, H. H. (1982). The development of concepts of social interaction: Children's understanding of nice and mean. Dissertation Abstracts International, 42(11), 4578B.

Hanson, N. R. (1961). Patterns of discovery. Cambridge, England: Cambridge University Press.

Harter, S. (1986). Cognitive-developmental processes in the integration of concepts about emotions and the self. Social Cognition, 4, 119-151.

Harter, S., & Pike, R. (1984). The pictorial scale of perceived competence and social acceptance for young children. Child Development, 55, 1969-1082.

Huckfeldt, R. R., Kohfeld, C. W. & Likens, T. W. (1982). Dynamic modeling: An introduction. Beverly Hills, CA: Sage publications.

Inhelder, B., & Piaget, J. (1958). The growth of logical thinking from childhood to adolescence (A. P. S. Seagrim, Trans.) New York: Basic Books. (Originally published, 1955).

Inhelder, B., & Piaget, J. (1964). The early growth of logic in the child (G. A. L. D. Papert, Trans.) New York: Harper & Row. (Originally published, 1959).

Jackson, E., Campos, J. J., & Fischer, K. W. (1978). The question of decalage between object permanence and person permanence. Developmental Psychology, 14, 1-10.

Kitchener, K.S., & Fischer, K.W. (1990). A skill approach to the development of reflective thinking. In D. Kuhn (Ed.), Developmental perspectives on teaching and learning thinking skills. Contributions to Human Development, Vol. 21, pp. 48-62. Basel, Switzerland: S. Karger.

Kitchener, K. S., Lynch, C. L., Fischer, K. W., & Wood, P. K. (1993). Developmental range of reflective judgment: The effect of contextual support and practice on developmental stage. Developmental Psychology, 29, 893-906.

Kohlberg, L. (1969). Stage and sequence: The cognitive developmental approach to socialization. In D. A. Goslin (Ed.), Handbook of socialization theory and research (pp. 347-480). Chicago: Rand, McNally.

Kohlberg, L. (1984). The psychology of moral development: The nature and validity of moral stages. San Francisco: Harper & Row.

Kohut, H. (1971). The analysis of the self. New York: International Universities Press.

Lamborn, S. (1986). Relations between social-cognitive development and personal experience: Understanding honesty and kindness in relationships. Dissertation Abstracts International, 47(8), 2959A.

Lamborn, S. (1986). Relations between social-cognitive development and personal experience: Understanding honesty and kindness in relationships. Dissertation Abstracts International, 47(8), 2959A.

Lazarus, R. S. (1991). Emotion and adaptation. New York: Oxford University Press.

Leslie, A. (1987). Pretense and representation: The origins of "theory of mind". Psychological Review, 94, 412-426.

Levine, R. L., & Lodwick, W. (1992). Parameter estimation and assessing the fit of dynamic models. In R. L. Levine & H. E. Fitzgerald, (Eds.), Analysis of dynamic psychological systems: Vol. 2 (pp.119-150). NY: Plenum Press.

Lewis, M. D. (2000, in press). The promise of dynamic systems approaches for an integrated account of human development. Child Development.

Loevinger, J. (1976). Ego development: Concepts and theories. San Francisco: Jossey-Bass.

Mascolo, M. F., & Fischer, K. W. (1998). The development of self through the coordination of component systems. In M. Ferrari & R. Sternberg (Eds.), Development of self-awareness across the lifespan (pp. 332-384). New York: Guilford.

Mascolo, M. J., Fischer, K. W., & Li, J. (in press). Dynamic development of component systems of emotions: Pride, shame, and guilt in China and the United States. In R. J. Davidson, K. Scherer, & H. H. Goldsmith (Eds.), Handbook of Affective Science Oxford, U.K.: Oxford University Press.

Mascolo, M. F., Fischer, K. W., & Neimeyer, R. (1999). The dynamic co-development of intentionality, self, and social relations. In J. B. Brandstädter & R. M. Lerner (Eds.), Action and self-development: Theory and research through the lifespan (pp. 133-166). Thousand Oaks, CA: Sage.

Matousek, M., & Petersén, I. (1973). Frequency analysis of the EEG in normal children and adolescents. In P. Kellaway & I. Petersén (Eds.), Automation of clinical electroencephalography (pp. 75-102). New York: Raven Press.

Ochs, E., & Jacoby, S. (1997). Down to the wire: The cultural clock of physicists and the discourse of consensus. Language in Society, 26, 479-505.

Parke,R.D., Ornstein, P.A., Rieser, J.J., & Zahn-Waxler, C. (Eds.). (1994). A century of developmental psychology. Washington DC: APA.

Peirce, C. S. (1982-1993). Writings of Charles S. Peirce. Bloomington, IN: Indiana University Press.

Perkins, D. N., & Salomon, G. (1989). Are cognitive skills context-bound? Educational Researcher, 18, 16-25.

Piaget, J. (1952). The origins of intelligence in children (M. Cook, Trans.) New York: International Universities Press. (Originally published, 1936).

Piaget, J. (1954). The construction of reality in the child (M. Cook, Trans.) New York: Basic Books. (Originally published, 1937).

Piaget, J. (1951). Play, dreams, and imitation in childhood (C. G. F. M. Hodgson, Trans.) New York: Harcourt Brace. (Originally published, 1946).

Piaget, J. (1957). Logique et équilibre dans les comportements du sujet [Logic and equilibrium in subjects' behavior]. Études d'Épistémologie Génétique, 2, 27-118.

Piaget, J. (1970a). Genetic epistemology. New York: Columbia University Press.

Piaget, J. (1970b). Structuralism (C. Maschler, Trans.) New York: Basic Books. (Originally published, 1968).

Piaget, J. (1983). Piaget's theory. In W. Kessen (Ed.), & P. H. Mussen (Series Ed.), Handbook of child psychology: Vol. 1. History, theory, and methods (pp. 103-126). New York: Wiley.

Piaget, J. (1985). The equilibration of cognitive structures: The central problem of cognitive development (T. Brown & K. J. Thampy, Trans.) Chicago: University of Chicago Press. (Originally published, 1975).

Piaget, J., Grize, J. B., Szeminska, A., & Bang, V. (1968). Épistémologie et psychologie de la fonction (Epistemology and psychology of the function]. Études d'Épistémologie Génétique, 23.

Pipp, S., Fischer, K. W., & Jennings, S. (1987). Acquisition of self and mother knowledge in infancy. Developmental Psychology, 23(1), 86-96.

Pipp, S. L. (1990). Sensorimotor and representational internal working models of self, other, and relationship: Mechanisms of connection and separation. In D. Cicchetti & M. Beeghley (Eds.), The self in transition: Infancy to childhood (pp. 243-264). Chicago: University of Chicago Press.

Port, R. F., & van Gelder, T. (Eds.). (1995). Mind as motion: Explorations in the dynamics of cognition. Cambridge, MA: The MIT Press.

Prigogine, I., & Stengers, I. (1984). Order out of chaos: Man's new dialogue with nature. NY: Bantam.

Reznick, J. S., & Goldfield, B. A. (1992). Rapid change in lexical development in comprehension and production. Developmental Psychology, 28, 406-413.

Rose, S. P., & Fischer, K. W. (1998). Models and rulers in dynamical development. British Journal of Developmental Psychology, 16, 123-131.

Ruhland, R., & van Geert, P. (1998). Jumping into syntax: Transitions in the development of closed class words. British Journal of Developmental Psychology, 16(Pt 1), 65-95.

Shaver, P. R., Schwartz, J., Kirson, D., & O'Connor, C. (1987). Emotion knowledge: Further exploration of a prototype approach. Journal of Personality and Social Psychology, 52, 1061-1086.

Siegler, R. S. (1981). Developmental sequences within and between concepts. Monographs of the Society for Research in Child Development, 46(2, Serial No. 189).

Skinner, B. F. (1938). The behavior of organisms. New York: Appleton-Century-Crofts.

Skinner, B. F. (1969). Contingencies of reinforcement: A theoretical analysis. New York: Appleton-Century-Crofts.

Thelen, E., & Smith, L. B. (1994). A dynamic systems approach to the development of cognition and action. Cambridge, MA: The MIT press.

Vallacher, R., & Nowak, A. (1994). Dynamical systems in social psychology. New York: Academic Press.

van der Maas, H. L., & Molenaar, P. C. M. (1992). Stagewise cognitive development: An application of catastrophe theory. Psychological Review, 99, 395-417.

van Geert, P. (1991). A dynamic systems model of cognitive and language growth. Psychological Review, 98, 3-53.

van Geert, P. (1998). A dynamic systems model of basic developmental mechanisms: Piaget, Vygotsky, and beyond. Psychological Review, 105, 634-677.

Van Parys, M. M. (1983). The relation of use and understanding of sex and age categories in preschool children. Dissertation Abstracts International, 45(2), 700B.

von Bertalanffy, L. (1968). General systems theory. New York: Braziller.

Vygotsky, L. S. (1962). Thought and language (E. H. G. Vakar, Trans.). Cambridge, MA: MIT Press.

Vygotsky, L. (1978). Mind in society: The development of higher psychological processes (M. Cole, V. John-Steiner, S. Scribner, & E. Souberman, Trans.). Cambridge MA: Harvard University Press.

Watson, M. W., & Fischer, K. W. (1977). A developmental sequence of agent use in late infancy. Child Development, 48, 828-835.

Watson, M. W., & Fischer, K. W. (1980). Development of social roles in elicited and spontaneous behavior during the preschool years. Developmental Psychology, 16, 484-494.

Watson, M. W., & Fischer, K. W. (1993). Structural changes in children's understanding of family roles and divorce. In R. R. Cocking & K. A. Renninger (Eds.), The development and meaning of psychological distance (pp. 123-140). Hillsdale, N.J.: Erlbaum.

Watson, M. W., & Getz, K. (1990). The relationship between Oedipal behaviors and children's family role concepts. Merrill-Palmer Quarterly, 36, 487-505.

Werner, H. (1957). The concept of development from a comparative and organismic point of view. In D. B. Harris (Ed.), The concept of development.). Minneapolis: University of Minnesota Press.

Westerman, M. A. (1990). Coordination of maternal directives with preschoolers' behavior in compliance-problem and healthy dyads. Developmental Psychology, 26(4), 621-630.

Yan, Z. (2000). Dynamic analysis of microdevelopment in learning a computer program. Unpublished doctoral dissertation, Harvard Graduate School of Education, Cambridge, MA.

Zeeman, E. C. (1976). Catastrophe theory. Scientific American, 234(4), 65-83.