Microdevelopment: A process-oriented perspective for studying development and learning

Nira Granott and Jim Parziale

This book presents a new, process-oriented view of development and learning focusing on microdevelopment. Microdevelopment is the process of change in abilities, knowledge, and understanding during short time spans. The defining attributes of microdevelopment are embedded in its name. "Micro-" pertains to short time scales, periods ranging from months to just a few minutes. "Development" indicates the evolving nature of the process, the real-time (on-line) evolution of skills and abilities of development and learning. Studies of cognitive, motor, and emotional microdevelopment commonly focus on processes in which lower-level abilities are reorganized into higher-level ones (Werner, 1957). In this way abilities are examined as they are constructed and before they become automatic reactions (Vygotsky, 1978; Werner, 1957). The microdevelopmental perspective allows researchers to follow the evolution and modification of the functional models that people use (Inhelder et al., 1980). When observing microdevelopment, researchers examine processes within specific task contexts, while people solve problems, perform assignments, or make discoveries. They analyze the process of change, identify its attributes and patterns, and look for the processes that underlie quantitative and qualitative change (Miller & Coyle, 1999; Siegler, 1996). Researchers focus, then, on the "how" of development and learning, on giving explanations, which is the ultimate goal of science (Flavell, 1984).

As editors, we are grateful to all the authors who contributed to this book their outstanding and pioneering work on microdevelopment. We are honored by the opportunity to put together the first collected work in this new and developing area. We are also grateful for the diligent effort and support of Sarah Caro, Senior Commissioning Editor, Sophie Read, the superb copy-editing of Virginia Catmur, and to the Cambridge University Press production team for their splendid work in publishing this book.

Editing this book and writing the editorial chapter were supported by National Science Foundation (Grant SBR-9818959), Texas Higher Education Coordination Board TARP grant, Timberlawn Psychiatric Research Foundation grant, and University of Texas at Dallas to the first author, and University of Massachusetts at Boston to the second author.

State-oriented vs. process-oriented approaches

Although development and learning are evolving processes, their understanding has been based on comparing knowledge and abilities at different ages. In pre- and posttests or cross-sectional designs, researchers compare abilities at different time points. Even longitudinal studies only provide a series of snapshots taken at different points in time. Using these approaches, researchers can compare the product of change, but not its process (Miller & Coyle, 1999). These approaches make inferences about processes by comparing static states, which is similar to inferring motion from still pictures.

Comparisons of static states can indicate global developmental trends and provide an understanding of a person's abilities at specific ages. However, such comparisons leave a significant gap in understanding how change occurs (Siegler & Crowley, 1991). The gap is a necessary by-product of state-based methods, because change is inherently dynamic. It occurs throughout time, during a process, not at a point in time but *across* points in time (Granott, this volume).

With technological innovations that have made video technology accessible, simple, and inexpensive to use, researchers can easily document processes. Availability of computers and specialized software has also facilitated the analysis of videotaped data, as did the development of new analytic methods, such as those provided by the dynamic systems approach. These innovations have supported a natural evolution in psychology from analysis of *what* develops to analysis of *how* people learn and develop, and from general identification of structures that characterize developmental stages to analysis of processes of real-time activity within specific contexts.

As the different chapters in the book demonstrate, when using a process-oriented perspective, researchers explore how people learn, adapt to new circumstances and environments, change their behavior, discover new strategies, solve unfamiliar problems, create new understanding, and develop new abilities. Process-oriented researchers ask new questions and change research procedures. They look for innovative analytic methods and devise different prediction techniques. Microdevelopmental researchers are developing new theories that account for a wide variety of findings that have not been predicted nor explained by state-oriented theories. The changes in the study of development and learning are so substantial, that several researchers view process-oriented approaches as marking a paradigm shift in these areas (Granott, 1998a; Lee & Karmiloff-Smith, this volume; Thelen & Smith, 1994).

Microdevelopmental research provides educators and other practitioners with powerful tools that extend the understanding of learning practices and enrich assessment methods. Microdevelopmental research is especially promising for validating performance-based assessment in education, which has triggered much interest in the last few years (Baker, O'Neil, & Linn, 1993). Microdevelopment-based methods may prove to be more valid and informative than conventional methods of evaluation or standardized achievement tests. Better understanding of the process of change in school can help educators make classroom practices more effective and efficient. They can restructure approaches to support better learning, design empowering curricula, and create programs that stimulate development. To improve education, more needs to be known about how progress occurs during learning.

Development and learning

The study of microdevelopment unites the areas of development and learning. In the past, views about the relationship between development and learning have covered a wide range. Some approaches collapsed one into the other, viewing development as nothing but learning, or learning as nothing but development (Kuhn, 1995b). Other approaches considered development and learning as separate processes, substantially different from each other. For example, Piaget (1964) identifies development with a spontaneous process and learning with a process provoked by another person, a teacher or an experimenter. In this view, development was characterized by inventive construction, whereas learning by exogenous acquisitions and repeated responses, not structured or reorganized (Piaget, 1970). The extreme approach, which divides learning and development into two distinct processes, maintains that development is deep, fundamental, irreversible, and mostly internally controlled, whereas learning is superficial, simplistic, reversible, automatic, and externally driven (see, for example, review in Kuhn, 1995b; Halford, 1995; Zimmerman, 1995).

The degree of distinction between learning and development depends on the theoretical frameworks that define these processes. If every form of cognitive acquisition were defined as learning, development would have consisted only of a succession of learning situations (Piaget, 1970, p. 112). When behaviorism declined and other approaches, such as constructivist learning, emerged, researchers expected effective learning to create cognitive restructuring, internalization, and transfer. Recently the distinction between development and learning has been examined again with theories and models that make a wide range of claims (see the collected work in Kuhn, 1995a; Liben, 1987; Strauss, 1993).

Research on microdevelopment is based on tasks that traditionally have been related to development as well as learning. Researchers also use tools that apply to both development and learning and serve as "arching methodologies" (Granott, 1998b). Because these methodologies make it possible to compare processes in development and learning, it is not surprising that many of the findings of microdevelopment have highlighted the similarities between development and learning.

Similarities between development and learning

Studies of microdevelopment show that attributes of development are similar to those expected from learning processes and vice versa. On the one hand, development is like learning: it includes much variability and reversibility. New research on microdevelopment shows that variability is one of the most consistent attributes of developmental processes. Correspondingly, variability is a most prominent issue in this book and appears in each of its chapters (see below).

On the other hand, learning is similar to development. Studies of microdevelopment show learning processes with trend of growth (see, for example, the chapters of Gelman et al., Granott, and Parziale). Learning does not necessarily require external support from another person, but rather can evolve through self-scaffolding (Granott, Fischer, and Parziale, this volume) and an internal feedback loop between meta-level operators and strategies (Kuhn, this volume). Reversibility in learning processes is reinterpreted as a facet of progress. For example, Goldin-Meadow & Alibali (this volume) show that increased mismatch between information expressed in speech and gesture (which could have been presented as reversibility in matched information) is related to progress toward more correct understanding. Similarly, Siegler (1996, this volume) shows that use of less advanced strategies is part of a progress defined in terms of increasing frequency of more advanced strategies. Granott (this volume) shows that recurrent regressions and backward transitions (which could be seen as reversibility in knowledge during learning) have important developmental roles, serving as a major mechanism for creating progress. Granott (1998b) demonstrates that learning processes can have fundamental developmental attributes: a high growth rate, qualitative restructuring of knowledge, and shifts to higher levels of thinking that are neither guided nor supported by a more capable person. As Siegler (this volume) indicates, this is the generative attribute of learning.

Microdevelopment, then, refers to processes of change in both learning and development. Not all learning processes show microdevelopment, just as there may be plateau-like periods in development. Processes of "developing learning" or "developmental learning" (i.e., learning that has developmental attributes; see Granott, 1998b), as well as periods of progress in abilities in development, are periods of microdevelopment.

By analyzing microdevelopment, researchers gain increasing understanding of processes of change. Their findings shed light on the common attributes that underlie development and learning and can promote progress in both.

Studying microdevelopment: The microgenetic and dynamic systems approaches

Microdevelopment can be studied with different methods. We use the term "microdevelopment" to refer to a developmental phenomenon of changes in abilities across short time spans. This book focuses on two approaches for studying microdevelopment: the microgenetic and dynamic systems approaches.

Terminology: Microdevelopment, the microgenetic method, and dynamic systems approach

The terms "microdevelopment" and "microgenesis" have been used interchangeably. The term "microgenesis" was coined by Werner (1956) as referring to processes that unfold during a short time span (Flavell & Draguns, 1957). A year later, Flavell and Draguns reviewed studies based on this approach and used both the terms "microgenesis" and "microdevelopment." Since then, researchers have used either the term "microgenesis" (e.g., Brown, 1982; Kuhn, 1995c; Siegler & Crowley, 1991) or "microdevelopment" (e.g., Fischer, 1980; Karmiloff-Smith, 1979) or both (e.g., Metz, 1993). In this book, researchers use both terms to indicate development during short time spans.

However, we find that the modern use of the term "microgenesis" is somewhat ambiguous. During Werner's time, "genesis" was used to signify "development." For instance, Werner (1948, p. 38) discusses "genetic experiments," referring to experiments on development. Today, "genetic experiments" would be understood as experiments on genes, and the term "genetic" usually refers to phenomena related to the genes. By contrast, the term "microdevelopment" is more easily and intuitively understood as indicating a micro time scale of development.

Therefore, we suggest the use of the term "microdevelopment" for the developmental phenomenon.

On the other hand, we use the term "microgenetic method" to refer to a specific method for studying microdevelopment, as is currently well accepted in the literature (e.g., Kuhn, 1995c; Siegler, 1996; Siegler & Crowley, 1991).

The microgenetic method

The microgenetic method is defined by three main attributes (Siegler & Crowley, 1991). (1) It spans a period from the beginning of a process of change until a stable state. (2) The density of observations is high relative to the period of change. (3) Intensive trial-by-trial analysis focuses on inferring processes that triggered quantitative or qualitative change. Some studies are even based on continuous documentation, which captures an entire process of change (Granott, 1998c, this volume; Parziale, this volume). By making continuous or nearly continuous observations, researchers obtain data that can capture developmental transitions and give direct access to the actual process of change.

Dynamic systems approach

The other approach for studying microdevelopment is based on application of tools and concepts developed through mathematical analyses of dynamic and especially nonlinear systems: the dynamic systems approach. Thelen and Corbetta (this volume) suggest that dynamic systems theory is a metatheory that provides rationale for studying microdevelopment, which involves real, dynamic, process-based data. The dynamic systems approach offers powerful concepts that help in explaining the developmental process. For example, the concept of self-organization denotes processes in which existing components of a system are interrelated and assembled into new forms of organization (see the chapters by Granott; Lee & Karmiloff-Smith; Lewis; and Thelen & Corbetta). Emergence, another concept discussed in the dynamic systems literature, refers to system-induced creation of new structures out of existing structures. The concept of attractor – a stable state toward which the system tends to evolve – is very useful for describing developmental stages (Thelen & Smith, 1994) or the stability that a system approaches during microdevelopment (Lewis, this volume; Granott, Fischer, & Parziale, this volume).

As this book demonstrates, the combination of the microgenetic method and dynamic systems approach, when used for studying microdevelopment, makes an important contribution for understanding the nature of change in development and learning. Process-oriented research makes this contribution through a rich pool of diverse types of studies.

Types of microgenetic studies

Microgenetic studies vary along five dimensions. These dimensions are independent of each other and all of them appear in this book.

1. Natural vs. novel task Researchers can focus on a natural occurrence or familiar task that children or adults use in the normal course of development. Such are, for example, spontaneous mismatches between speech and gesture (Goldin-Meadow & Alibali, chapter 3). Other examples include infants' reaching and interlimb coordination (Thelen & Corbetta, chapter 2), interrelations between emotion and cognition (Lewis, chapter 7), and infants' crying (van Geert, chapter 12).

By contrast, a novel task is one that participants are unlikely to encounter in circumstances other than experimental settings. Examples of novel tasks in this book are infants' treadmill stepping (Thelen & Corbetta, chapter 2) and the wuggle study, in which participants were asked to explore unfamiliar robots (Granott, chapter 8). Another example is Karmiloff-Smith's (1981) experiment, in which children devised a notational system with directions for driving an ambulance to a hospital (see Lee & Karmiloff-Smith, chapter 9). Similarly, the evolution of Darwin's theory can be classified as a novel task, uncharacteristic of regular, everyday life (Fischer & Yan, chapter 11).

Natural and novel tasks are two opposite ends of a continuous dimension (Granott, 1993). Many tasks fall in between these extreme cases. For example, although a conservation task is contrived, children do encounter issues of conservation in everyday life. By the same token, the task of explaining the experimenter's reasoning is induced by experimental conditions (Siegler, chapter 1), but children do develop the ability to consider another person's way of thinking in the natural course of development. Similarly, tasks that are part of children's learning experiences at school may be planned by teachers or researchers (see Gelman, Romo, & Francis, chapter 10; Parziale, chapter 6), yet to various degrees they blend with other learning activities that have become part of children's everyday experience at school. Another example is children's reasoning about causality in relation to the features of a boat or a car (Kuhn, chapter 4), which is devised by a researcher, yet children may encounter other tasks that require similar reasoning when playing with some educational toys.

The last examples correspond to tasks that fall in between the extremes of natural or novel tasks. These tasks can be grouped into one or more categories if this dimension is treated as a categorical or ordinal scale. Alternatively, it can be treated as a continuum, with weights assigned to values between the two extremes of the dimension, much like the fuzzy-logic-based method suggested by van Geert (chapter 12).

2. Intensive and concentrated vs. routine or interspersed experience Microgenetic studies vary along another dimension – the intensity and concentration of the targeted experience. Some studies focus on an intensive experience that is concentrated within a relatively short period of time. Some examples for such activities in this book are solving conservation problems (Siegler, chapter 1) or boat/race-car problems (Kuhn, chapter 4); treadmill stepping (Thelen & Corbetta, chapter 2); building bridges (Parziale, chapter 6); or exploring a robot (Granott, chapter 8). This type of study often promotes accelerated microdevelopment.

Other tasks correspond to more routine or interspersed experience. Such are, for example, the science-into-ESL activity (Gelman et al., chapter 10), theory development (Fischer & Yan, chapter 11), and, fortunately for parents, babies' crying (van Geert, chapter 12). Such activities often correspond to a slower rate of change.

Like the previous dimension, the intensity of experience can be a continuous dimension with tasks' intensities corresponding to various values along the dimension. For example, Goldin-Meadow & Alibali (chapter 3) report studies that differ on this dimension, varying from weekly experience over a period of weeks to a concentrated experience during one hour. Lewis (chapter 7) discusses emotional experiences that vary in their time scales from seconds (microdevelopment of emotional appraisal and action), through minutes, hours, or days (mesodevelopment related to moods), and to months and years (macrodevelopment of personality dispositions).

3. Individual vs. socio-interactive experience Some microgenetic studies focus on an individual and examine changes in the individual's behavior across time. In this book, infants' crying (van Geert, chapter 12), babies' reaching and stepping (Thelen & Corbetta, chapter 2), children's notational systems (Lee & Karmiloff-Smith, chapter 9), students' science-into-ESL learning (Gelman et al., chapter 10), and Darwin's theory development (Fischer & Yan, chapter 11) are examples for such studies.

Other studies focus on interactive processes. Interactive processes themselves comprise diverse types of interactions (Granott, 1993). Studies can include interactions among peers (as in Granott, chapter 8; Granott, Fischer, & Parziale, chapter 5; Kuhn, chapter 4; and Parziale, chapter 6). Other studies focus on interaction between a child and a more capable partner, such as an experimenter (as in Siegler's chapter) or teacher (as in Goldin-Meadow & Alibali's chapter).

This dimension can be treated as dichotomous categories (either individual or interactive), as an ordinal scale, or as a continuous dimension. In the latter two cases, the dimension can measure the degree of collaboration or the asymmetry of expertise (Granott, 1993).

4. Spontaneous vs. training or guided activity Another dimension on which microgenetic studies vary is a distinction between spontaneous, unconstrained activity and an activity that provides guidance or training. Spontaneous activities can evolve without a corrective feedback from another (e.g., gesturing while solving equations in Goldin-Meadow & Alibali's chapter; designing a notational system, reviewed in Lee & Karmiloff-Smith's chapter).

At the other end of the dimension, activities involve interaction that provides guidance or training. As Thelen & Corbetta (chapter 2) note, researchers can deliberately facilitate discoveries through coaching, training, practice, or scaffolding support. For example, Siegler (chapter 1) presents an activity in which the child gets feedback from the experimenter. By the same token, Gelman, Romo, and Francis (chapter 10) describe activities with teaching–learning interactions between the teacher and the students.

As in the previous dimensions, there are studies that map on values between these two extreme ends. For instance, during spontaneous activities, participants may receive feedback from the task materials, by observing how the latter change as a result of their own actions or by adjusting to changes in the materials. Such are the cases of the boat and race-car problems in Kuhn's chapter; treadmill stepping in Thelen & Corbetta's chapter; bridge building in Parziale's chapter; and robot exploration in Granott's chapter. Darwin's theory building (Fischer & Yan, chapter 11) may be considered in this category, as Darwin continually developed his theory by comparing its predictions or implications with ongoing observations. In a similar vein, spontaneous activities in real-life situations may involve varying degrees of feedback from the social environment, and sometimes no feedback at all. Such may be studies involving babies' crying (as in van Geert's chapter) or emotional development (Lewis, chapter 7).

The examples demonstrate that this dimension too can be treated either as categorical/ordinal or as a continuous dimension with varying degrees of feedback.

5. Natural vs. laboratory setting The fifth and last dimension for comparing microgenetic studies is the environment in which the data are collected. On the one hand, there are natural, familiar settings from the participants' everyday life. Such settings are used in Gelman et al.'s (chapter 10) and Parziale's (chapter 6) studies. Both of these studies take place within school, in the students' regular learning environments. On the other hand, many studies are performed in the laboratory. Most of the studies presented in the book fall under this category.

Unlike the previous dimensions, this one appears to be dichotomous. However, if studies simulate and blend aspects of the natural and laboratory settings, this dimension can become continuous too.

Advantages of studying microdevelopment

The study of microdevelopment makes an important contribution for understanding development, learning, and change. Its unique attributes manifest in the type of data collected, analyses performed, explanations offered, and implications inferred for both learning and development.

1. Data Dense data that are collected by using the microgenetic method have several benefits not obtained through state-oriented methods.

(i) Access to a process. Owing to dense sampling throughout a process of change, microgenetic data allow direct observations of processes. Microgenetic data give access to the process by documenting participants' actions (see the chapters by Thelen & Corbetta; Siegler), gestures (Goldin-Meadow & Alibali's chapter), vocalization (van Geert's chapter), conversations (the chapters by Granott; Granott, Fischer, & Parziale; Kuhn; Parziale), explanations to the experimenter (Goldin-Meadow & Alibali; Siegler), notes (Fischer & Yan; Gelman, Romo, & Francis), and concrete products (Parziale).

Microgenetic data are more detailed than data obtained through other methods (Siegler, this volume). These data provide access to the on-line process of learning and allow observations of people constructing new knowledge (Gelman et al., this volume; Kuhn, this volume). Such data make it possible to identify characteristic attributes, patterns, and mechanisms of change, which manifest in the *process* and cannot be detected in cross-sectional or conventional longitudinal data (Granott, this volume). Microgenetic data are a key factor for facilitating the analysis and identification of developmental transitions (Granott, Fischer, & Parziale, this volume). The opportunity to study the process of development and learning may be one of the potentially richest advantages of the microgenetic