Strauss, S. (2000). Theories of cognitive development and their implications for curriculum development and teaching. In B. Moon, M. Ben-Peretz, and S. Brown (Eds.), **Routledge international companion to education** (pp. 33-50). London: Routledge.

Theories of Cognitive Development and Learning and Their Implications for Curriculum Development and Teaching

Sidney Strauss

Tel Aviv University

Author's address: Sidney Strauss, School of Education, Unit of Human Development and Education, Tel Aviv University, Tel Aviv, Israel 69978. E-mail: sidst@ccsg.tau.ac.il

Child Cognitive Development and Learning

Theories of Cognitive Development and Learning and Their Implications for Curriculum Development and Teaching

The focus of this chapter is on one aspect of developmental psychology: cognitive development. So as to put the chapter into a framework, a few words about the state of contemporary psychology and child development are in order.

Contemporary Psychology

Human beings are too complex to understand and research in their entirety. For sake of convenience, we divide humans into parts that seem reasonable to us today. These parts are the domains we study in contemporary psychology. Figure 1 presents a view of what those domains are, the theories we have constructed to describe those parts, and the major theoreticians who have developed those theories.

Contemporary psychology is undergoing rapid and far-reaching changes. There were periods when little change was the order of the day, e.g., behaviorism held sway in Anglo-American psychology for the first 50 years of this century. A major reason for the deep changes in contemporary developmental psychology is the cognitive revolution that began in the mid-1950s. Areas now under the modern rubric of “cognitive psychology” were once a bastion of psychology. Learning, memory, sensory processes, and other subdomains were the hard science research parts of psychology. Today, these subdomains are being studied in departments of

cognitive sciences, which include the wet mind (brain sciences), philosophy, linguistics, mathematics, computer sciences (especially artificial intelligence), and others.

Another several decades of this trend might end up with psychology departments devoid of this area or psychology departments may combine with others, keeping the title cognitive psychology in the psychology departments. An example of the former comes from MIT whose psychology department, which was almost exclusively in the cognitive sciences, disbanded and became integrated into a new department of cognitive and brain sciences.

Although prophecy is fraught with problems, I believe that the future of psychology will see this parting of the ways continue, where cognitive psychology will become part of other departments and the remainder of psychology will have more of a helping professions flavor to it. Having written this, I now turn to developmental psychology.

Developmental Psychology

Figure 1 was written with an eye towards developmental psychology's place in the larger scheme of psychology. Notice that in Figure 1, the developmental part is above the others. This is because development is not content-free. Something develops. There is physiological development, personality development, cognitive development, etc.

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The changes in psychology, described above, are being felt in developmental psychology and are leading to a split in the ranks. The result is two major variants of developmental psychology.

One variant is based on a positivist, laboratory experimental approach to cognition, where the search is for cognitive universals. One recent lead in this realm is taken by adherents of information processing theories (Elman, Bates, Johnson, Karmiloff-Smith, Parisi, & Plunkett, 1996). Here there is an attempt to describe cognitive development in terms of connectionist models of psychology and brain functioning.

The second variant is a cultural psychology that bears witness to the influences of Vygotsky's socio-historical approach on our understanding of development (Shore, 1996; Stigler, Shweder, & Herdt, 1990). Here the view is postmodern in nature, where narratives and texts play a central role in understanding human development. The search is for contextual influences on human behavior and development, where universals are eschewed.

In this chapter, I deal with one aspect of the general area of child development: cognitive development. Within the area of cognitive development, I deal with learning and development. I also address the nature of the relations between curriculum development, teaching, and theories of learning and development.

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Curriculum Development

Elsewhere (Strauss, 1997), I defined, curriculum as the external manifestation of an underlying conceptual system about: (1) the nature and structure of subject matter that is being taught, (2) children's' conceptions (sometimes preconceptions or misconceptions) of that subject matter, and (3) mechanisms of cognitive change, i.e., learning and development.

As for the mechanisms of cognitive change, buried in curricula are assumptions curriculum writers have about how learning and development occur in children's minds. Generally, these assumptions are uninspected. They are tacit and between the lines. But investigators can unearth these assumptions through hermeneutic text interpretation.

A simple example here might be helpful to illustrate the point. Often one sees in mathematics curricula the following: a problem type is presented; solutions to two problems are demonstrated; and the children who are studying from the curriculum are presented 15 similar problems for solution. One could surmise from this rather familiar description that the curriculum developer believes that children learn through demonstration and practice. I do not quibble with that implicit description of the nature of the mechanism that leads to learning. Instead, I use this as an example of how one could analyze a section of a curriculum to determine the nature of the curriculum developer's implicit model of children's learning and development.

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One purpose of the present chapter is to elaborate on different kinds of theories of learning and development cognitive development psychologists have constructed and then to show their potential influence on curriculum development. In the discussion section, I return to curriculum development in light of the exposition of these theories.

Teaching

Teachers, when teaching subject matter, have conceptual systems that describe children's minds and how learning and development take place in those minds. Research indicates that teachers have two main kinds of conceptual systems, called mental models (Johnson-Laird, 1983; Norman, 1983), that guide their behaviors (Mevorach & Strauss, 1996; Strauss, 1993, 1996).

Kinds of Mental Models

The first is an in-use mental model (Schon, 1983). This is the mental model teachers have about children's learning that is exhibited when they actually teach in the classroom. The second is an espoused mental model (Schon, 1983). This is the mental model teachers show when they speak about how they teach. Both kinds of mental models are claimed to lead to behaviors: actual teaching behaviors in the case of teachers' in-use mental models and their verbal descriptions of how they would teach in the case of their espoused mental model.

How espoused mental models are inferred. We infer implicit espoused mental models from what teachers say explicitly about how they teach. We do not

ask teachers what they think children's minds and learning are because when we have done that, teachers tell us what they remember about Piaget and Vygotsky from their university courses. Instead, we ask them how they teach difficult material and infer from what they tell us what we believe are their implicit mental models of learning. This inference is reasonable because teachers teach so that learning will take place in children's minds.

An example might be helpful here. In discussions with teachers about how they teach difficult subject matter, they might say that complex material is difficult for children, and that breaking up the complex materials into parts makes the material easier to learn. This is the explicit part of what teachers say. We infer from that explicit statement that a part of the teacher's implicit mental model holds that smaller piece of knowledge can get into the mind more easily than larger pieces of knowledge. This is implicit because it was not what the teacher said, but what we inferred had organized that statement. Teachers' implicit espoused mental models underlie their explicit statements.

The espoused mental model of children's minds and learning we found among teachers bears a family resemblance to 1960's information processing models such as that of Atkinson and Shiffrin (1968).

In the discussion section of this chapter, I elaborate on the topic of teaching, the nature of the espoused mental model, and its connections to theories of learning and development, the topic of our next section.

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Theories of Learning and Development

Debate abounds concerning definitions of learning and development and their places in theories of cognitive developmental psychology and educational theory and practice (Kuhn, 1995; Liben, 1987; Strauss, 1993a). Notions of learning and development are neither fixed nor agreed upon. Instead, they are defined by the theory in which they are embedded. In other words, much of what is said about definitions of learning and development depends on the theory of the speaker's persuasion.

In this section, I lay out various positions about learning and development as they pertain to theories that imbue cognitive and developmental psychology.

Debate about learning and development has energized the fields of cognitive and developmental psychology and education over the distant and not too distant past. Theorists' positions about learning and development result from the various stances taken with respect to the following issues: origins (i.e., With what do infants come into the world?), how what infants are born with changes over time, relations between the individual and the environment, and domain-general versus domain-specific knowledge.

As for this last issue, there has been considerable controversy over the years about what cognitive and developmental psychologists should search for: domain-general or domain-specific systems. As for domain-general systems, diverse data and phenomena that can be described by a single model fulfill the sought-after

criteria of parsimony and power. That description has been the aim of most cognitive and developmental psychologists.

As for domain-specific cognitive systems, research findings in neuropsychology, the effects of brain damage for cognitive functioning, representations of experts in a domain, and more all point to a certain encapsulation or domain-specificity of cognitive entities.

To anticipate some of what follows in this chapter, I believe this either-or view of domain general versus specific knowledge restricts debate, but that is the way many people in the field often cast it these days. There are exceptions, though. Case (1985, 1992, 1993), Feldman (1994, 1995), and Karmiloff-Smith (1992, 1994) attempt to find ways to include both domain-general and domain-specific systems in their theories.

I briefly summarize these issues with respect to nine theories: nativism, behaviorism, structuralism, information processing, the sociohistorical approach, and four interstitial theories: a neo-Piagetian theory, a theory of nonuniversal development, the naive theories approach, and the representational redescription approach.

Nativism

Nativists are influenced by the rationalist philosophical tradition. Radical nativists, such as Fodor (1980, 1983), argue that infants are born with complete and abstract knowledge about aspects of their world. Using language as an

example, the argument is that infants are born with a universal grammar (UG). They are also born with learning devices that allow any child to learn, in my example, any language.

The arguments posed by Fodor (1980, 1983) about human cognition have had serious consequences for cognitive developmental psychologists. He has claimed, in so many words, that human cognition does not allow for development. Fodor's (1983) thesis about the modularity of mind is the basis for this claim.

He argues that the mind is genetically specified and has independent modules that are specified for the kinds of inputs that come to it from the environment. A language module, for instance, is specified for language input. Domain-specific transducers deal with the domain-specific environmental information. Holding a picture to our ears will not activate language transducers. In this view, then, cognition is modular, domain-specific, and genetically hard-wired in the neuronal architecture. These modules are self-contained and need no recourse to general, domain-general cognitive goals. They allow automatic outputs that are driven by environmental stimuli.

He does allow for central processing, however, which he claims is domain-general. Computations in the central processing part of cognition lead to beliefs about the world. These beliefs are what are in long term memory concerning the environment. They concern belief fixation (also see Fodor, 1980), the accumulation of declarative beliefs about the world, and procedural planning of

actions in that world. Fodor (1983) claims that the search for central processing components and processes is the pursuit for an after-the-important part of human cognition. In his view, the work done by the modules and their transducers are the significant part of cognitive work. When what gets worked out at the modular level gets passed on to the central processing system, the interesting part of cognition has already happened. As a consequence, he argues, much research and theory in cognitive psychology gets in at the wrong place.

A second reason radical nativists argue that, in principle, there is no development is that, in their view, it is impossible to get from less to more powerful mental structures (Fodor, 1980). Because this is impossible, one must engineer an infant who has the most powerful structures from birth. The moment radical nativists take that position, there can be no development because the most powerful structures are in place from the very beginning.

Change that takes place, then, must be learning, and learning must be deductive. Here the argument is that, very roughly, children deductively test hypotheses about their environment (e.g., their language) and get feedback about whether or not their hypotheses are confirmed or disconfirmed. And where can these hypotheses come from? From the complete UG with which they are born.

Radical nativists place the greatest emphasis on the individual and the innate knowledge each of us is born with. The environment is the place where the

hypotheses about the world get tested. It has been argued that this environment is, by definition, impoverished.

In short, the radical nativists argue that children are born with complete, abstract knowledge; in principle, development cannot occur; deductive learning is the explanation for change; learning is domain-specific; and the individual's innate modular and encapsulated knowledge is the main part of the individual-environmental interactions.

Behaviorism

The radical version of behaviorism (Bijou & Baer, 1961, 1965 Skinner, 1953) is that infants are born with neither knowledge (tabula rasa) nor organization. With respect to what knowledge and cognitive equipment the infant brings into the world, radical behaviorism occupies the pole at the other extreme of the continuum occupied by the radical nativists. Behaviorists claim that infants are born with capacities to discriminate aspects of the environment, respond to it, generalize, and so on.

Because their position is that infants are born without knowledge and, as a result, they are unstructured with respect to knowledge, radical behaviorists are unlikely to claim that the child will eventually have mental structures. This is because such a claim would force them to find an explanation as to how an unstructured mental system becomes structured. Because there is no restructuring there is no development. Cognitive change that does take place, then, is learning.

Ironically, the position that there is no development and only learning is common to the radical nativists and the radical behaviorists. The nature of learning is very different, of course, for advocates of the two theories. For the nativists, it is deductive hypothesis testing, whereas for the behaviorists, it is inductive. I elaborate a bit on the behaviorist position here.

Radical behaviorists argued that learning - the capacity to form associations inductively in a lawful way - is the basis for the knowledge gained about the world. The environment impinges on us, and we form associations about it in such a way that the more we are exposed to a particular environment, the stronger the association, and the closer the aspects of the environment are in time and space, the more likely the association will be formed. The former is called the law of frequency, and the latter is called the law of contiguity.

Behaviorists have the environment as the main element in the relations between the individual and the environment. The external environment is what is to be noted and copied internally.

In short, radical behaviorists claim that infants are born without knowledge; development does not occur because there are no cognitive constraints on the initial (knowledge-free) system; laws of inductive learning are the sole explanation for cognitive change; the search is for domain-general mechanisms of learning; and the environment is the main part of the individual-environment interactions.

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Structuralism

Structuralists, such as Piaget, argue that infants are born with a weak structure of reflexes that transforms itself over time. Relations between the structure of reflexes and mental structures on the psychological plane have to do with the biological roots of psychological development. How one goes from one to the other is, of course, a puzzle yet to be solved by structuralists.

Because structuralists posit that infants begin life with a structure, the likely ensuing position is that their future cognitions will also be structured. The issue then turns to the direction and nature of development that proceeds from relatively weak to relatively powerful mental structures (Fodor, 1980). The position taken by Piaget and his followers is that this development takes the form of qualitatively different structures that are transformed in an invariant sequence.

Learning, in the structuralist view, is the application of mental structures to new content. Mental structures limit what can be learned because one cannot apply a mental structure that does not exist or has not yet been constructed. In this sense, development sets constraints on learning.

Structuralists maintain an intermediate position between the radical nativists and the radical behaviorists about individual-environment relations. They are avowedly interactionist in the sense that there is a subtle give and take between the environment and the structure. Assimilation, accommodation, and the equilibration of mental structures are major organizing principles for Piaget (1970).

One of the purposes of these structures is to maintain a state of equilibrium with the environment (adaptational equilibrium) and with itself (organizational equilibrium). The mechanism of cognitive development is disequilibrium of the two types just noted. In the case of adaptational disequilibrium, the mental structure cannot completely account for discrepant environmental information. Organizational disequilibrium occurs when the child contradicts herself, where the contradiction is the result of conflicting mental structures the child has developed. I have more to say about this in the section on Curriculum Development and Theories of Learning and Development.

Despite this principled interactionist position, that Piaget thought separated him from the radical nativists and radical behaviorists, Karmiloff-Smith (1992, 1994) recently claimed that there is a common view held by radical behaviorists and Piagetian structuralists. Both claim that infants are born without knowledge. If infants are without knowledge, how do they acquire or construct it (choose your theory when you choose your term)? Both give the same answer: through domain-general devices. As stated above, for the radical behaviorists, the device includes the capacity to discriminate environmental features, generalize, and form associations inductively. For the structuralists, the device is the assimilation-accommodation-equilibration complex as it gets expressed through the structures.

The domain-general system Piaget posits does not allow for domain-specificity in infancy and afterwards. He argues that domain-specific and innately

specified modules do not format environmental input. Instead, that input gets acted upon by the same mechanisms, regardless of the nature of the data from the environment. These mechanisms are controlled by the representational structures that are posited to develop over time in the now-famous sequence Piaget argued describes the cognitive development of mental structures.

In sum, structuralists claim that development occurs, and what develops are structures. Learning, then, is constrained by development. Infants are born with a domain-general structure of reflexes that have no domain-specific modularity. The individual-environment relations are interactionist. It is in these interactions that the child's actual developmental trajectory gets worked out and is the result of a mixture of what the structure offers as possibility and what the environment affords as reality.

Information-Processing Approaches

Information-processing theories are somewhat atheoretical. They are, of course, part of a general worldview, but they are not explicitly ideological in the sense that the three previous theories are.

The theories I present emphasize developmental aspects of information processing, but these aspects are not a prerequisite for information-processing approaches. Information-processing approaches that do deal with development are quite varied: production systems (Klahr, 1984), rule assessment (Siegler, 1981), skill acquisition (Fischer, 1980), and so on. There does not seem to be consensus

among these approaches about how much knowledge the child is born with and how it is organized. Yet, there are some unifying themes to which most information-processing advocates adhere. One is that thinking is information processing. Others are the emphasis placed on the ways children represent knowledge, how they transform information, and the processing limitations that constrain the inductive inferences they can make about their world.

What develops according to these approaches? The answer depends on the approach, of course, and given space limitations, I can only hint at what answers have been offered to this question.

The novice-expert shift is a candidate for what develops. Domain-specific knowledge representation has been described in terms of novice-expert dimensions. The novice's domain-specific knowledge representation differs from the expert's on a number of dimensions: its knowledge base, organization, problem solving, and so on. These dimensions set limits on what and how much can be learned. For example, a child who has a larger knowledge base about a particular domain and whose knowledge representation is deeper than another child will learn more about new material when it is presented.

Another candidate for what develops is working memory limitations. There is controversy about whether or not working memory changes. Among those who believe there are age-related working memory changes is Case (1993). The argument is that working memory limitations set constraints on the inductive

inferences that can be made. And as working memory increases with age, so do the kinds of inferences children can make.

In these two examples, the developmental aspect pertains to constraints placed on the information-processing system, be they processing constraints on knowledge representation and organization or on working memory constraints.

Learning can be the result of several processes that occur alone or in concert. Among them are strategy construction (Siegler & Shipley, 1987), automatization (Case, 1984), encoding (Siegler, 1981, 1984), generalization (Klahr, 1984), and analogy construction (Gentner, 1983).

Automatization can be used to demonstrate what learning mechanisms might be. Case (1984) argued that within the information-processing constraints on working memory, children are able to learn new material through automatization. When automatization occurs, space is freed up in working memory for other information to be taken into account. Notice that the information-processing capacity has not changed here. Instead, within the constraints of that capacity, one can deal with more information by, say, automatizing processing.

The bulk of the information-processing approaches place the burden of the individual-environment relations on the environment. Physical input from the environment gets transformed as it makes its way to the place where it is eventually stored. But there is no question that the individual also plays a role here in that knowledge representation of the new material will influence what and how

much will get learned.

In sum, information-processing approaches are somewhat atheoretical. Many do not make claims about the nature of the knowledge and its organization that infants are born with. Some approaches claim that development occurs with respect to changes in the constraints on the information-processing system that limit the kinds of inferences that can be made. These constraints are at the working memory level. And, to use Fodor's terminology, they are part of the central processing system, not at the level of transducers. Learning overcomes processing constraints via mechanisms such as strategy construction, automatization, encoding, generalization, and analogy construction. And the environment is the dominant factor in environment-individual relations.

The Sociohistorical Approach

The sociohistorical position, as advanced by Vygotsky (1978, 1987), maintains a two-track position about human cognitive processes: the natural and the cultural. Natural processes follow the path of maturational underpinnings and the environment supplies information for those underpinnings to get played out. These lower mental processes are not reflective and are the result of direct, personal experience with the environment.

For the cultural track, the social environment is crucial, as are the tools that are used for understanding and engaging the environment. There are two basic kinds of tools: material and psychological. Material tools mediate between the individual and nature. For example, a hoe has a handle designed to fit the individual's hand and a plate built to fit the material world. The hoe mediates between the individual and nature, both literally and metaphorically.

Psychological tools mediate between individuals in their social interactions. These are signs, symbols, and discourses. These semiotic systems are also used by individuals to change their own psychological processes. Languages we have constructed come to organize the ways we understand our environment, others, and ourselves. This idea gets picked up in the Discussion section where I present how theories of learning and development can effect curriculum development. This is the kernel of Vygotsky's (1987) general genetic law of cultural development. He claimed that all functions appear twice: first among people as an interpsychological category and then within the child as an intrapsychological category (Wertsch & Tulviste, 1992).

Having written this, I now turn to the roles of learning and development according to this approach. I begin with a caveat. There are at least two main understandings of these terms: Vygotsky’s (1987) and his modern-day interpreters.

In Vygotsky's (1978) view, learning goes beyond development and draws development in its wake. An individual's developmental level is her mature

knowledge as expressed when she works alone. Vygotsky (1987) called this the individual's actual knowledge. Learning in social interactions among individuals happens in the zone of proximal development (ZPD). What is learned in concert with others comes to be internalized, and what is learned becomes the new actual knowledge or the new developmental level. This learning with others creates and actualizes potential knowledge as individuals move towards a new developmental level. In this sense, learning is the leading edge of development. It creates new developmental levels.

One area where Vygotsky's modern-day interpreters differ from Vygotsky is in the sense in which the terms development and learning are used. Different than Vygotsky, they believe the terms are inadequate to describe what they have in mind. One reason for this has to do with the unit of what they believe changes with age. Newman, Griffin, and Cole (1989), for example, suggested that the unit of analysis for cognitive change is neither the invariant mental structures (as Piaget would have it) nor the mental processes that transform information (as appealed to by information processing people). Both exist in the mind of individuals. It is also not in the environment. Instead, the unit is in the social interaction between individuals and between them and the environment.

This unit requires a language of description different than the ones we currently use. The alternative suggested by Vygotsky's interpreters is to view learning as a social practice, an activity that takes place among people in social

contexts. The unit of analysis is located in that nexus. When one takes this view, the notions of learning and development lose their usual meaning.

The emphasis on individual-environment interactions for learning and development lean strongly toward the social activity that is between the individual and the environment. However, Wertsch and Tulviste (1992) noted problems with this emphasis, mostly because of the lack of construction in the ZPD, as Vygotsky (1978) described it. Vygotsky's view of internalization has a ring of absorption, rather than the sound of reconstruction. Contemporary adherents of the socio-historical approach have added constructivism to Vygotsky's theory, so as to make it more in line with current views of cognitive functioning, even though those views are not derived from the original socio-historical approach.

In sum, the socio-historical approach engineers infants with two tracks: the natural and the cultural, without making claims about how much knowledge the infant is born with. Vygotsky claimed that learning proceeds in advance of development as the zone of proximal development is created. Some contemporary socio-historical theorists and researchers believe that these terms are obsolete and not useful anymore. And Vygotsky places great emphasis on the roles of social activity in the ontogenetic development of cognition.

Interstitial Theories

Four interstitial theories have taken some positions from different theories. Case's (1985, 1993) neo-Piagetian theory, Feldman's (1994) theory of non-

universal development, the naive theories approach (Carey, 1985; Spelke, 1990, 1991), and representational redescription theory, developed by Karmiloff-Smith (1992, 1994).

Neo-Piagetian Theories

Neo-Piagetians blend structuralist tenets with those of information processing. Among the neo-Piagetians are Case (1982, 1992, 1993), Demetriou & Efklides (1988), Fischer (1980), Halford (1980, 1982, 1993, 1995), and Pascual-Leone (1970, 1988). I use Case's work to illustrate what neo-Piagetians are up to.

Case's approach is structuralist in that he seeks general structural organizations that have properties of stage-like development. For example, their development is sequential. They are qualitatively different from each other. They are domain general. The forms of learning are modified by the structures children construct. And cognition is influenced by general developmental rules.

The point of departure from the structuralist approach in Case's theory is that he uses an information-processing frame to describe the processes that occur when the mental organization deals with information. The move from describing mental structure via logical and mathematical structures, as did Piaget (1970), to describing them in terms of information-processing systems, as does Case, led Case to descriptions of cognition and development that are different from Piaget's.

These differences are inspired by contemporary learning theory as advanced by information processing adherents. One difference is that, in addition to the

structures being domain general (which is Piagetian), they also cover domain-specific knowledge (which is aligned with information processing approaches). Also, although there are general developmental cognitions that are restructured (Piagetian), Case posits that cognitive change also occurs because of specific experiences (information processing).

In short, neo-Piagetians seek to determine general cognitive structures and their developmental sequences while, at the same time, they search for domain-specific knowledge organizations that are the products of specific experiences with the environment.

In sum, Case's version of neo-Piagetian theory posits that infants are born with M-power and it develops. There are radical shifts in the levels at which children's M-power gets structured in mental organizations. The content and organization of these structures are not determined only by experience. The structures apply across a very broad range of domains. And these structures are part of children's general developmental level and are not acquired only by formal schooling or specific experiences. Learning and development, then, are both domain-specific and domain-general.

Non-Universal Development

Feldman's (1994, 1995) interstitial theory of nonuniversal development has elements of both the structuralist and the sociohistorical approaches. He argues that most of cognitive development is about nonuniversals, yet cognitive

developmentalists attempt to describe universal development. Ontogenesis proceeds in the following order of intellectual achievements: universal (e.g., early Piagetian stages), pancultural (e.g., quantity), cultural (e.g., arithmetics), discipline-based (e.g., mathematical psychology), idiosyncratic (e.g., mathematical models that describe formal operations in Piaget's, 1970, theory), and unique (e.g., those creative changes in models made by an individual that lead to a reorganization of understanding the formal operations stage, a reorganization that is accepted by experts in the field).

The development of societies proceeds in the reverse order, beginning with the unique achievements of individuals who make an impact on their subfields, perhaps on their fields, and, in rare cases, on their cultures.

Several matters arise when one takes Feldman's (1994) position. First, he takes the structuralist position that structures and developmental sequences exist. Individuals develop through these stages. The sequence of development, then, is in the domains that individuals develop through.

Second, developmental transitions are powered by the same mechanisms Piaget and his followers claimed underlie cognitive development: structural conflict of the adaptational and organizational varieties.

Third, developmental sequences are expressed in cultural domains. For example, in baseball, there are a number of levels of expertise through which to

develop, from the level of the sandlot novice through A, AA, and AAA levels arriving, possibly, to the major leagues.

Fourth, all nonuniversal developments take into account individual differences, creativity, and motivation, and require arranging special situations for learning to occur, such as schools, private lessons, and so on.

This opening up of cognitive developmental theory to the acquisition of nonuniversals makes structuralist theory, at least this variant of structuralist theory, more amenable to discussing its implications for education.

Feldman does not couch his theory in these terms, but it includes both domain-general and domain-specific organizations. The domain-general part pertains to universal developmental achievements, whereas the domain-specific part concerns the expressions of these domain-general cognitions in achievements in culturally-organized domain-specific areas.

In sum, the theory of nonuniversal cognitive development does not make claims about origins of structures and knowledge in the infant. Structures are the cognitive entities that develop, and their sequence is the result of a subtle blend between these structures' properties and the structure of the domain in question. Developmental sequences are as much in domains of cultures as they are in the minds of individuals. And there are both domain-general and domain-specific aspects to the theory.

Naive Theories Approaches

Those who advocate the naive theories approach usually uphold an amalgam of nativism and structuralism (Carey, 1985; Gelman, 1990).

Radical nativism, it will be remembered, seeks a description of innate domain-specific modules. Adherents of that approach argue that central processing, which is where domain-general beliefs get fixated, is the wrong level to seek lawful cognition and knowledge acquisition. As I have shown, radical nativism also shuns a developmental position.

There are nativists of another stripe, those who are not advocates of the radical position (Carey, 1985; Gelman, 1990). They claim that infants are born with considerable innately specified knowledge about their world, learning takes place within the constraints set by those specifications, and mental constructions occur within these constraints.

Advocates of the naive theories approach, then, seek out innate domain-specific characteristics of cognition, which aligns them with that aspect of radical nativism, while seeking rules of constructivist development, which is associated with structuralism. In short, this emerging position suggests that one can be both a nativist and a constructivist or, to use Gelman's (1990) terminology, a "rational constructivist".

Within the naive theories approach to cognitive development and learning, Carey (1985) proposed a rather advanced theory. She claimed that children have

theory-like conceptual structures. Abstractness and law-like coherence characterize theories, the phenomena in their domains, their explanatory mechanisms, the ways they produce interpretations of evidence, and more. The number of such domains is limited: biology, physics, language, space, number, and a few others.

Carey de-emphasizes domain-general knowledge and places great emphasis on domain-specific knowledge. The latter is within domains, such as biology, physics, language, etc. The wired-in, innately specified cognitions are domain-specific.

Carey (1985) further claimed that concepts in particular domains are part of larger naive or lay theories about that domain. One of the tasks of developmental psychologists who adhere to this theory, is to determine the nature of these naive theories about the domains under study.

Carey also claimed that because concepts are embedded in naive theories, conceptual change, which can be understood as development, can be viewed as similar to theory change in domains. For example, aspects of theory change in the sciences serve as a way to think about how the development of lay theories occurs in children (and adults).

The educational implications of the naive theories approach is that we can view learning through instruction, in the widest sense of this term, as the engine that drives development. Instruction, both formal and informal, leads to knowledge acquisition that leads, in a yet undetermined manner, to cognitive

development.

In short, the perspective here is that infants are born with innately specified knowledge about their world, which sets both information processing and theory structural constraints on their learning. Hence, there is emphasis on domain-specific knowledge. Children form concepts within large domains that have theory-like qualities. The development of concepts occurs in ways that resemble theory change in disciplines. Learning through instruction may lead to development. And the environment-individual complex is subtlely interactive.

A Theory of Representational Redescription

Karmiloff-Smith (1992, 1994) recently presented a theory of cognitive development that combines aspects of nativism, the sociohistorical approach, and structuralism. The nativist part that remains in her theory is the notion that human beings are born with domain-specific predispositions.

Mental constructions, thought to be built off the innate knowledge, are the rerepresentations humans construct about their world. What this means is that people internally represent their external environment (i.e., we mentally appropriate it). We then represent our representations (or rerepresent our environment) via various languages. These languages are cultural artifacts and, thus, are within the province of Vygotsky's socio-historical approach. Part of the rerepresentation includes changes from implicit to explicit representations. The emphases placed on these changes also have a sociohistorical ring to it. The

structuralist part, inherent in her theory, is that these rerepresentations are constructed, which is consistent with the constructivist position held by Piaget.

When melding theories that are quite different in their stances about essentials in human cognition, it is important to avoid producing a theory that is an eclectic patchwork quilt with parts taken from here and there, where these parts are slapped on to each other. Karmiloff-Smith has managed to do avoid that. To resolve the essential tensions between the nativist and structuralist approaches, she added a notion that allows both to sit side-by-side without serious conflict: representational redescription.

Karmiloff-Smith took on Fodor's (1983) claims about the modularity of cognition and argued against his notion in two main ways. First, she argued against the notion that innate modules are prespecified in detail. She made them more epigenetic than Fodor made them out to be. And second, she fuzzed up the sharp distinction Fodor made between prespecified modules and central processing.

Similarly, she took issue with some of Piaget's claims. Most important among the issues she chose to address is Piaget's position about domain-generality. She argued that it is difficult to hold Piaget's domain-general position alone with respect to infants' mental equipment. There is simply too much evidence from different quarters showing us that cognition is modularized.

So she rejected Fodor's claims for the notion of cognitive modules being encapsulated. Similarly, she rejected Piaget's notion of domain-general cognition,

where the same mechanisms of data processing occur without regard to the nature of the environmental input.

What does she offer as an alternative? First, she accepts the nativist idea of domain-specificity, but she includes the development of these modules, a notion that is unacceptable to radical nativists. And she accepts the structuralist notion of constructivism. Her alternative offers a way to put domain-specificity and constructivism together. To do so, she had to change, somewhat, the definitions Fodor gave of domain-specificity and modules and Piaget's domain-general constructivism. And in so doing, she invented the notion of representational redescription.

Karmiloff-Smith (1992, 1994) includes domain specificity of human cognition, where domains are physics, mathematics, biology, language, psychology, etc. She also allows what she terms "microdomains", which are subdomains such as addition in the domain of mathematics and psychological causality in the domain of psychology. Her major addition here is that she developed a recurrent phase change model that occurs at different times and for different microdomains and within each domain. One of the reasons for this move on her part is that it can account for both domain specific and general cognition. It also addresses how children's representations become increasingly flexible, an area that is missing in Fodor's (1983) account of cognition.

In her recurrent phase change model, Karmiloff-Smith (1986, 1992, 1994) argues that development involves three recurrent phases. The first learning phase is data driven and connected to the immediate environment. Children's performances here are successful in that they get to a level of behavioral mastery.

The second learning phase is more internally focused. Children's internal representations of knowledge in a microdomain have precedence over environmental data. The shift from phase 1 to phase 2 can lead to a drop in performance. The drop is in performance and not in the representational system that leads to that performance and, as a result, this is a case where a drop in performance signifies cognitive advance.

The third learning phase involves an integration of external environmental input and internal mental representations. This learning phase leads to children's correct productions but, although they are similar or even identical to the performances from phase 1, they are different in that they have different representational systems underlying them.

In addition to the learning that takes place in recurrent phase change, children's internal representations are formatted at least four levels: one level of implicit representation and three levels of explicit representations. These redescriptions of representations are redescriptions at a new format level and language of what was previously described at a lower format level. Among other

characteristics, movement through the format levels involves increasing consciousness of one's representational systems.

In short, Karmiloff-Smith's theory of representational redescription posits innate domain knowledge that is not modularized. Development involves an increasing modularization of representational systems and their increasing explicitness. As for the environment-individual interaction, both are important in different ratios at various phases of development. And the theory posits importance for both domain-general and domain-specific representations.

Summary

The brief discussion of nine major theories attempted to show that the position one takes about the origins of knowledge (i.e., what the child is born with) and issues related to domain-generality and domain-specificity has potential to constrain what theorists say about relations between learning and development, mechanisms of learning and development, and the nature of the relations between the individuals and their environment. I now briefly turn to what this has to do with curriculum development and teaching.

Curriculum Development and Theories of Learning and Development

In the introduction, I defined curricula as the external expression of an underlying implicit conceptual system held by the curriculum developer about the nature of the subject matter being taught, children’s preconceptions of that subject matter, and mechanisms that govern learning and development. Given my review

of theories of learning and development, it is appropriate to ask how the curriculum developer can engage them.

The main point here is that the understanding the curriculum developer has about the nature of children's learning guides her choices about which curriculum activities to include in the curriculum. An example might be useful here. Research on children's developing understandings of the concept of temperature can serve as a case-in-point.

Children's Developing Concepts of Temperature

An aspect of the concept of temperature can be tested by giving children two tasks: a qualitative and a numerical task. For the qualitative task, children are presented with two cups of water and are told that they are cold and are the same temperature. The experimenter then pours the water from the two cups into a third, empty cup and asks the children what the temperature of the mixed water is. The numerical task is identical to the qualitative task, except that the children measure the water's temperature in the two original cups and determine that they are both 10° C.

The developmental trajectory of children's solutions to the two tasks was found to be quite different. The qualitative task was solved correctly by most young children (ages 4-6); many older children (ages 7-9) solved it incorrectly; and still older children (ages 10 and older) solved it correctly. This unusual U-shaped behavioral growth curve, which was found for the qualitative task, and the drop in

correct responses over age was interpreted by Strauss (1982) and Strauss & Stavy (1982) to be a sign of cognitive advance.

The solutions children offered to the numerical task had a different behavioral growth curve. It was found that very few children solved the 10° C + 10° C task correctly, as most children argued that the mixed water was 20° C. It was only at age 11 that approximately 25% of the children solved that task correctly. A much lower percentage of children solved that task correctly at earlier ages.

The question before us is as follows: How would a curriculum developer construct activities whose main purpose is to foster learning so that children with incorrect understandings of the numerical problem would have a more adequate understanding of that problem after they did the activities of the unit's work pages.

The Structuralist Curriculum Developer

If the curriculum developer was a structuralist, she might attempt to create organizational conflict within the child. For example, she could build the activities in the following manner. She could ask children to: (1) mix same-temperature cold water, as in the qualitative task, (2) judge the temperature of the mixed water, and (3) note, on a qualitative thermometer (i.e., a thermometer that has qualitative readings on it, such as cold, tepid, hot) drawn on the work page, what the temperature of the mixed water was. She might then ask children to: (1) mix same-temperature water that was originally 10° C, (2) judge what the resulting

temperature should be when the original water was mixed, and (3) note on a numerical thermometer (i.e., the usual thermometer that has numerical readings of temperature) what the temperature of the mixed water was. Were the children who studied with these work pages similar to those found in Strauss & Stavy's (1982) research, they would mark the temperature of the mixed water on the qualitative thermometer as cold, whereas they would mark the temperature of the mixed water on numerical thermometer as 20° C.

The structuralist curriculum developer, in an attempt to create organizational conflict, could then pit these two ways of thinking in the hope that the children would realize that they are producing conflicting judgments. That could be done by asking the children to compare their markings on the qualitative and numerical thermometers and to see if they are marked at the same location. They could also suggest to the children that they might discuss the implications of their markings being at the same or different places. For a description of research that studied the above, see Stavy & Berkowitz (1980) and Strauss (1987).

The point here is that the structuralist curriculum developer could construct work sheets that would attempt to lead children to understand that they are producing conflicting judgment, which the curriculum developer believes comes from different mental structures.

How would a socio-historical curriculum developer create a curriculum unit to teach for a better understanding of the numerical concept of temperature?

The Socio-Historical Curriculum Developer

An adherent of the socio-historical approach, in an attempt to help children gain a better understanding of the numerical task for the temperature concept, would construct work sheets that are quite different than those constructed by the structuralist curriculum developer, expressing, of course, her sociohistorical understanding of how children come to learn.

A beginning place for the work sheets might be grounded in the nature of the symbolic systems being used to describe the water's temperature. After all, the qualitative and numerical tasks are identical in terms of physics. What makes them different, then, is the language used to describe the physical phenomenon we are studying.

We feel water's temperature sensorally. And we give those sensations names, depending on the language we use. We can call the water cold, hot, or tepid. Those are words from natural language and they are classificatory, nominal. We can also use comparative terms, such as "more" "less", and "same", all of which allow us to compare temperatures of water. And we can describe the water's temperature numerically by using the numerical scale etched on the thermometer, which is an instrument that was constructed for the purpose of measuring temperature. Carnap (1966) discusses these three measurement languages in a philosophical treatment of physics.

Our hypothetical curriculum developer of the socio-historical persuasion might build work sheets that have the children discuss the similarities and differences between the two tasks in terms of the languages we use to describe them. For instance, the work sheets might have the children discuss among themselves that the physics of the problem is identical but they languages used to describe the physics is different. The children could also discuss what the two languages give us in terms of (1) precision, (2) a sense of "closeness" to our intuitive knowledge, etc. And there could be discussions about the idea that humans constructed both languages and can be seen as alternative descriptions of the same physical phenomenon.

The work sheets were built to help children to understand that: (1) the two tasks of pouring water are identical, (2) the physics of the two tasks is identical, (3) two languages (natural and mathematics) can describe the same phenomenon, (4) the two languages have differences and similarities, (5) the two languages, as different as they are, should allow the same solution to the tasks because the tasks tap the same physics phenomenon.

Summary

The above intended to indicate how curriculum developers who are proponents of two approaches to learning and development might construct work sheets when they have before them identical developmental data, i.e., children solve differently (U-shaped and a gradually-increasing curve) two tasks

(qualitative and numerical) that tap an aspect of children's conceptions of temperature.

The structuralist curriculum developer believes that learning and development occur as a result of conflict and, as a result, the work sheets are constructed to induce, in our case, organizational conflict. The socio-historical curriculum developer believes that the semiotic system and consciousness about it and about our own cognition helps foster learning. As a consequence, the work sheets might have the children discuss the two semiotic systems (natural language and mathematics) and their relations to the identical physics task.

We now discuss a second arena where theories of learning and development influence educational matters: teaching.

Teaching and Theories of Learning and Development

Teaching is done to foster children's learning. When a teacher speaks about how she teaches or when she actually teaches, she indicates her understanding of the nature of children's minds and how learning occurs in those minds. This understanding is generally implicit, but it is there nonetheless.

In this section, I describe how teachers hold a particular view of children's minds and learning - an information processing view. I then show how a socio-historical view of children's minds and learning leads to different teaching.

The Information Processing Teacher

In the introduction, I outlined teachers' implicit espoused mental model of children's minds and learning. I now very briefly elaborate on it.

The mental model of children's minds and learning shows an engineering vision on the part of the teachers (Strauss, Ravid, Magen, & Berliner, 1998; Strauss & Shilony, 1994). The basic premise of this model is that the teacher possesses knowledge, and it is external to children's minds. Once one takes that position, two engineering problems follow: First, how does one get the external information inside the child's mind? And second, once it gets there, how can one move it along to the place where it gets stored or, in other words, gets learned?

In order for learning to occur, the content must first enter children's minds, and teachers conceive of children as having openings of a certain size that allow information to enter. Their notion of "opening size" recalls the notion of working memory capacity. Teachers believe that good pedagogy involves serving up knowledge in chunk sizes that can "get through" the openings. For example, teachers said that what makes some subject matter difficult is that it is too complex and, as a result, it may not be able to get "in" the mind. Here teachers see their task as reducing this complexity by breaking the material into component parts so that it will be able to enter the mind's opening. However, even were the material to be of the right complexity, it may never enter the mind if the child's affective states are not primed to receive the content. Conceived of metaphorically, the entrances to

children's minds have "flaps" that are open when children are attentive. If children are uninterested or unmotivated, the flaps go down and the material cannot enter the mind.

Teachers believe that once content gets through, it must somehow connect up with already-existing knowledge by means of analogies, associations, familiar examples, and so on. This corresponds to an elaborative-processing model. Accordingly, teachers believe they should facilitate connection-making between new and old knowledge. If there is no existing knowledge to get connected to, the new knowledge can get driven into memory through repetition, rehearsal, and practice. This new knowledge now becomes part of already-learned knowledge. How does the new knowledge affect the prior knowledge? Teachers believe that there are changes in the amount and organization of prior knowledge, the prior knowledge gets broadened and generalized, it is at higher levels of abstraction that what was in previous knowledge, and more.

These are some of the solutions to the two engineering problems that result from teachers' mental models of the structure of children's minds, how learning takes place in those minds, and how instruction fosters that learning. These solutions are seen within teachers' implicit information processing mental model of children's minds and learning. But, as shown, there are other models of children's learning and development and they, too, can be expressed in teaching. We now turn to a version of learning that is based on the socio-historical view.

The Socio-Historical Teacher

The socio-historical view of learning has a strong social component to it. Social interactions lead to learning and it is that very learning that draws development in its wake. Social interactions are of two sorts: social interactions between individuals, as in conversations, and social interactions between individuals and their culture, including artifacts.

As mentioned, the zone of proximal development was one of Vygotsky's many legacies that have significance for our ideas about learning and teaching. The idea here is that children have knowledge about the topic you want to teach them before you teach them. Teachers assess that mature knowledge, which is knowledge they have constructed with the assistance of others but which they hold autonomously at the time of assessment. Vygotsky (1987) termed this: children's actual knowledge.

Instruction is intended to help guide children from their actual knowledge to what Vygotsky termed their potential knowledge. This is the knowledge children and teachers co-construct as they engage in learning. The distance children travel from the actual knowledge to the potential knowledge is the zone of proximal development.

The conversations teachers have with children in this construction zone involve scaffolding. One part of important part of scaffolding, but not of the sort where teachers scaffold and children have their knowledge constructed for them, is

co-guiding. Teachers can assess what children's actual knowledge is and they have a lay of the land in terms of the places to which they want to help children move. Children do not have that lay of the land. If they had it, they would most probably be where the teachers want them to be. On the other hand, there are different routes to get to the places teachers have determined are worthwhile. Teachers cannot know which route is best for any one child, but the children know what is working during teaching, and what is not. In this understanding of teaching, the learner and teacher are partners who guide each other. For an elaborated version of teaching inspired by the socio-historical approach, see Newman et al. (1989). This socio-historical view of teaching is clearly different than the information processing view that was found to be the dominant view held by teachers (Strauss et al., 1998; Strauss & Shilony, 1994).

Summary

I presented nine major theories of child cognitive development, with emphasis on how they view learning and development. The differences between the theories were shown to be rather large. I then showed how some of these theories have consequences for two aspects of educational practice: curriculum development and teaching. In usual practice, curriculum developers and teachers are not aware of the theories of learning and development that guide their practice. I showed that were these two educational practitioners to be aware of the theories they hold and the nature of alternative theories, their curriculum development and

teaching decisions would most likely be richer than those they make without that awareness.

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Figure 1 Caption: Subdomains of Psychology

Child Cognitive Development and Learning

	AREAS OF DEVELOPMENT						
SCHOOLS OF THOUGHT	Physio-logical	Social	Cognitive	Personality	Moral	Motiva-tional	Emotional
Nativism			Chomsky Fodor				
Behaviorism		Bandura Mischel	Skinner Estes	Miller	Berlyne		Skinner
Structuralism		Damon	Piaget Werner	Mehrebian	Kohlberg Turiel		Greenspan
Information Processing			Klahr Siegler				
Socio-Historical			Vygotsky Cole Wertsch				
Neo-Piagetian			Case Fischer Halford				
Non-Universal			Feldman				
Naïve Theories			Carey Gelman Keil Wellman				
Representa-tional Redescription			Karmiloff-Smith				