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NOOPLASIS: 10 + 1 POSTULATES ABOUT THE FORMATION OF MIND

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Abstract

This article is about nooplasis. That is, the article outlines a general model about the dynamic organization and development of mind and it draws the implications of this model for learning and instruction. This is done in terms of 10 postulates concerned with the architecture of mind, its development and dynamics, and the nature of learning, and a general postulate concerned with the dynamic relations between the various systems of mind and also mind and education. Specifically, the model postulates that the mind involves systems oriented to the understanding of the environment and of itself, in addition to general processing functions. It is also postulated that the development of each of the systems is partially autonomous and partially constrained by the development of the other systems, and that it involves both system-specific and system-wide mechanisms of development and learning. Finally, it is argued that these postulates suggest a model of constrained constructivism which leads to a conception of learning in schools which differs considerably from what is suggested by the Piagetian or the Vygotskian conception of constructivism.

Baldwin's (1894) *The development of the child and the race* was published over 100 years ago. In this insightful and far-reaching book Baldwin put down three of the most important building blocks of the psychology of cognitive development. Specifically, first, he advanced the assimilation-accomodation model of cognitive change. Second, he described a four-stage sequence of cognitive development involving a prelogical stage associated with infancy, a quasilogical stage associated with the preschool years, a logical stage associated with the primary school years, and a hyperlogical and extralogical stage associated with adolescence and adulthood. Third, he elaborated on the idea that ontogeny recapitulates phylogeny, and thus linked cognitive developmental theory to the theory of evolution which was thriving in those years.

Piaget took up Baldwin's ideas and he developed them to the extreme. In a sense the history of the field of cognitive development largely overlaps Piaget's biography. From

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about the early 20's to 1980, Piaget formulated the most wide and complex theory in the history of psychology. In fact, his theory is one of the very few psychological theories to have been seriously considered by many other fields, such as education, philosophy, and sociology. However, the fate of scientific theories, like the fate of all living beings, is one and unavoidable: to reproduce, multiply, and vanish. If they are strong enough to survive, they do so through their offsprings and descendants. Piaget's theory was very strong in this regard. Thousands of psychologists saw the gold that was there and they attempted to test and evaluate the theory. Many of its assumptions must be preserved in our present theories. However, today, Piagetians, neo-Piagetians, or meta-Piagetians, all agree that the time is ripe for a new theory of cognitive development. And other fields including developmental neuroscience, evolutionary theory, and dynamic systems theory strongly concur to move in the direction of formulating a new theory of cognitive development, and while the precise theory is not yet very clear, the general outline and the basic dimensions are already discernible, at least in my eyes.

My aim in this article is to sketch this outline, grossly define the dimensions, and draw the implications of this theory-to-come for learning and instruction. Thus, I will state a number of postulates which I believe summarize generally accepted evidence and which therefore capture widely shared ideas about cognitive development. These postulates will relate to (1) the architecture of the mind, (2) its basic characteristics during development, (3) the dynamics and mechanisms underlying its development, (4) the nature of learning, and (5) the nature of education from the point of view of a general theory of cognitive development. I use the term *nooplasis* to refer to all of these processes. This word does not exist in the dictionary. I have created it by combining two Greek words, the words "nous", which means "mind", and "plasis", which means "construction" or "formation" both as a state and as a process. Thus, this word is able to denote at one and the same time the architecture, the development and dynamics, and the education of mind.

The Architecture of Mind

Postulate 1: The Mind is a Hierarchical, Multisystem, and Multidimensional Universe

The evidence which has accrued over the years strongly suggests that the mind involves both domain-specific and domain-general systems which are organized hierarchically on a number of different levels.

The Domain-Specific Systems.

The domain-specific systems involve processes that represent and process different types of objects and relations in the environment. Because the mind and the environment are functionally and structurally attuned to each other, individuals tend to organize their interactions with reality into *domains of thought* that preserve the dynamic and figural peculiarities of different *reality domains* (Demetriou, 1996; Demetriou, Efklides, & Platsidou, 1993). Therefore, the systems of mind and their dynamic organization evolved to cope with the demands posed by different systems in the environment, and so domain specificity or modularity of mind reflects a kind of readiness to decode and deal with specific types of relations in the environment as efficiently as possible.

Admittedly, there is no general agreement as to what domains there are in the mind, and different research programmes have identified different types of domains. Research on the organization of problem-solving processes, such as our research (Demetriou et al., 1993) has identified domains which depend on the type of relations involved, such as categorical, quantitative, causal, spatial, and social relations. In fact, each of these domains constitutes very complex *specialized capacity spheres (SCSs)*, which are themselves hierarchically organized and which involve many dimensions. That is, each of these systems involves three kinds of components: ready-made kernel elements, operations or computational functions, and knowledge and beliefs.

Kernel elements constitute a particular kind of structure within a SCS which evolved to cope with particular structures in the environment which are of adaptive importance to the organism. Thus, kernel elements match relations in the environment which are typical of the reality domain to which this SCS is affiliated (Demetriou & Valanides, in press). Categorical perception, subitizing, perception of causality, depth perception, and face perception are examples of kernel elements in each of the SCSs mentioned above. Operations refer to systems of action, overt or covert, that the thinker brings to bear on different aspects of the domain to which each SCS is affiliated. For instance, categorization strategies, the four arithmetic operations, variation of a supposed causal factor, mental rotation, and turn-taking in social interactions are examples of operations in each of the SCSs. Knowledge and beliefs are the products of the functioning of the kernel elements and the operations. This knowledge accumulates over the years as a result of the interactions between a SCS and the respective domain of reality.

It must be noted that some of these domains (that is, the quantitative and the spatial) are with us for many years (Thurstone, 1938). Others have been mapped as autonomous domains (the categorical and the causal) by our research (Demetriou & Efklides, 1985; Demetriou et al., 1993; Shayer, Demetriou, & Pervez, 1988). The domain of social understanding is a rather recent addition to the list of autonomous modules. In his research, Case has recently mapped all but the causal SCS and has proposed a language for specifying the semantic characteristics of each of them (Case & Okamoto, 1996).

However, other researchers point to different types of domains. Specifically, research on the understanding of different phenomenological aspects of the world has identified three domains: the biological, the physical, and the psychological (Karmiloff-Smith, 1992). These domains are supposed to be differentiated on the basis of ontological rather than relational and computational characteristics. That is, they reflect the fact that entities involved in each of these domains differ from those involved in the others in important respects, such as their appearance and behavior.

These two types of domains are not incompatible. In fact, it seems plausible that the relations which characterize relationally differentiated domains run across the ontological domains. That is, all types of relations can be found in each of the three ontologically distinct domains mentioned above. For instance, there are categorical, quantitative, causal, or spatial relations in the biological, the physical, and the psychological worlds, although these relations are not entirely the same in the three domains. For instance, biological causality (such as the genetic transmission of characteristics) involves peculiarities that are not present either in physical or psychological causality (it is constrained by species membership, it requires mating, etc.). Physical causality requires the transmission of energy. Psychological causality may take place in fractions of a second, and it does not require any energy or the intervention of any medium. Imagine mood variations caused by the memory of an unpleasant encounter. Thus, it may be the case that each of the ontologically based domains involves a set of defining characteristics which function as markers of the relationships that define the relationally based domains. These markers enable the thinker to grasp a given type of relationship as an example of a particular ontological domain. Future research will decipher how the two types domains are related and how their relationships change with development.

The Domain-General Systems.

By definition, domain-general systems take the domain-specific systems as their input and constrain their functioning. Research in the last 20 years or so suggests that there are two domain-general systems: a *processing system* and a *self-awareness and self-regulation system*.

The processing system involves functions which define how much information can be processed simultaneously at a particular phase in development. There is compelling evidence that processing of very different types of information, such as verbal, visuo-spatial, and numerical is governed by the same constraints and undergoes uniform changes with growth (Case, 1992; Kail, 1988; Halford, 1993; Pascual-Leone, 1970). This evidence has been taken to imply that at least some aspects of the representation and processing of any kind of information are under the control of a general processing system. The closest approximation to this system in the classical theory of intelligence is Spearman’s (1927) *g*. Our research suggests that this system is defined by three distinct but interrelated parameters: (1*) speed of processing* (the maximum speed at which a mental act can be properly executed under conditions of maximum facilitation); (2) *control of processing* (the ability to inhibit processing of dominant but goal-irrelevant information and focus on goal-relevant information); and (3) *storage* (a dynamic field in which the currently needed information can be represented and operated on) (Demetriou et al., 1993; Spanoudis, Demetriou, Platsidou, Kiosseoglou, & Sirmali, 1996).

We use the term *hypercognitive system* to denote the self-awareness and self-regulation system (the adverb "hyper" in Greek means "higher than" or "on top of", or "going beyond", and indicates the supervising and coordinating functions posited for this system). This system involves processes which direct self-mapping and the mapping of other minds, and which are used to steer cognitive functioning according to the demands and the goals of the moment. This level involves three distinct but interdependent systems: (1) *the person’s own model of the mind* (awareness of different cognitive functions such as attention, memory, and inference, and awareness of specialized processes such as those involved in the SCSs); (2) *the person’s own model of intelligence* (this model specifies what is and what is not intelligent in a given environment); and (3) *one’s own cognitive self-image* (this specifies the person"s representations about her own intellectual strengths and weaknesses, preferences, etc.) (Demetriou et al., 1993; Demetriou, Kazi, Platsidou, Sirmali, & Kiosseoglou, 1997).

The domain-general processes constrain, boost, and direct the functioning and development of domain-specific systems, while in turn feed, inform, and expand the functioning and development of the domain-general systems. This synergetic relationship may also exist between the domain-specific systems themselves or between the domain-general systems themselves. In Fischer & Bidell (in press) terms, the systems of mind "are not simply interdependent but *interparticipatory*. True integration means that the systems participate in one another's functioning" (p. 24, emphasis in the original). According to this conception, the architecture and functioning of mind merge to co-define each other into *dynamic systems*. In these systems, structure cannot easily be dissociated from function because it refers to the "dynamic patterning and relating of components that sustain the organized activities that define life and living things" (Fischer & Bidell, in press, p. 9) in their interpenetration and internetworking with their environments.

It must be stressed that research in such diverse fields as evolutionary psychology (Cosmides & Tooby, 1994; Donald, 1991), neuroscience (Thatcher, 1994), and the psychology of individual differences (Gustafsson, 1994) strongly suggests that the picture of mind depicted above is generally accurate, even if it requires correction or completion in some places. That is, evolutionary theorists argue that evolution has sculpted special purpose circuits which have gradually come under the control of higher order self-mapping skills. This evolutionary sculpture can be seen directly in the architecture of the brain, which involves sets of superimposed structures, some of which are impressively specialized vis-à-vis the environment (such as the visual or the verbal cortex) and others (such as the frontal lobe), which function as general purpose systems for planning and control. Finally, individual differences explain the evolutionary sculpture (that is, differences between individuals in regard to the various levels and systems of mind provide a survival advantage to the species as a whole), which are explained by the architecture of the brain (that is, relative differences in different brain areas are transformed into differences in cognitive performance and development), and they are thus the means by which the cognitive researcher accesses to the architecture of mind through the avenue of function.

Postulate 2: The Levels and Modules of the Mind Obey Different Formal Rules

Piaget believed that a basic equivalence between the psychological and the logical architecture of human intellect must exists. His foundational conviction that the mind involves, at a deep level, a common *structure d'ensemble* which governs the organization of all domains of thought, such as categorical, quantitative, causal, and mathematical thought led him to propose that this structure can be fully modeled by some kind of logic (the group of displacement, the logic of functions, the logic of concrete operational groupings and the logic of the lattice and the INRC group structure at the stage of sensorimotor, preoperational, concrete and formal operational intelligence, respectively). I accept Piaget's belief that logic can be used to model the organization of the mind; obviously, logic is a mind-made system that formalizes the mind's postulates about reality and itself.

However, the architecture of mind as depicted by my theory suggests that no single logical system can suffice. Alternatively, there is a need for different logics to model the peculiarities of each different system. The first step in this direction would be to show that the various environment-oriented domains of thought, that is the SCSs sketched above, cannot all be modeled by the same logical system. Indeed, we have recently presented a series of logically based proofs which show that each of the five SCSs involves a unique element that is characteristic of the domain, but is unanalyzable by logic (that is, the specification of essential characteristics, the inclusion of an element to a broader quantitative construct, causal necessity, and the representation of wholeness and the analogue nature of representation, for the qualitative-analytic, the quantitative-relational, the causal-experimental, and the spatial-imaginal SSS, respectively). Moreover, we have also shown that this unique essential element is readily handled by intuition and cannot be reduced to any of the others (Kargopoulos & Demetriou, in press).

Demonstrating the logical irreducibility of the SCSs is only the first step en route to the complete logical modeling of the mind. Important steps in this process may be the specification of the logical properties of the computational processes involved in each of the various SCSs, the various aspects of the hypercognitive system, and of the very processes which are used by the hypercognitive systems to specify the similarities and differences between various computational processes. This process of modeling the mind has not even begun (however, see a discussion on this issue by Bickhard, Engel, Pascual-Leone, and Smith who comment extensively on our (Kargopoulos & Demetriou, in press) attempt to formalize the SCSs.

The Character and Process of Development

Postulate 3. The Mind Develops Along Multiple Roads: It Evolves (1) from Being Perceptually Driven and Action-Bound to Self-Guidance, Reflection and Self-Awareness; (2) from Fewer and Reality-Referenced to More and Reciprocally Referenced Representations; and (3) from Global and Less Integrated to Differentiated But Better Integrated Mental Operations

According to Piaget's theory, cognitive development evolves over four stages: the stages of sensorimotor (from birth to 2 years), pre-operational (2 to 5 years), intuitive (5 to 7 years), concrete (7 to 11 years) and formal thought (11 to 15 years). These stages were intended as descriptions of the organization and the possibilities of the human mind at successive phases of life. Testing of Piaget's theory has shown that these stages cannot be taken at face value. That is, many claims about what capabilities are present at particular ages and how various processes are interrelated have been shown by evidence to be inaccurate (Brainerd, 1978; Demetriou et al., 1993). However, these stages do seem valid as general frames for the kind of phenomena that can be understood at successive phases of life and of the individual's general approach to problem-solving (Chapman, 1988; Demetriou, 1998). In fact, despite differences in terminology, several neo-Piagetian theorists, (i.e., Case, 1992; Halford, 1993; Fischer, 1980; Moshman, 1990; Pascual-Leone, 1970) have integrated these four stages in models they proposed as alternatives to Piaget's system and they have presented extensive and diverse empirical evidence to support them. Thus, below I will use these frames to summarize commonly shared views and evidence related to the general trends and directions of development in the various levels and systems of mind, as summarized in the section on architecture.

Specifically, it is indeed true that pre-language infants are able to recognize and abstract meaning from complex patterns of configurations and relations in the environment (Butterworth, 1997). However, no one would disagree that pre-language infants are highly attracted by variations in their perceptual environment and that they are primarily oriented to doing rather than to thinking and reflection. Moreover they do not seem aware of themselves or of their representational nature.

Preschoolers are able to represent the world and the mind and they can operate on representations. In fact, they posses a theory of mind that enables them to understand and explain others' behavior and even manipulate and deceive them (Chandler, Fritz, & Hala, 1989; Wellman, 1990). However, they are frequently clumsy in doing so, they are easily deceived by appearances (Flavell, Green, & Flavell, 1986), and they have difficulties to understand the representational functions of symbols (DeLoache, Uttal, and Pierroutsakos, this issue). They are much more efficient when they have to work with few (one or two) rather than many dimensions or representations (Case, 1992). Moreover they are more at ease under conditions which are overly suggestive of the meaning and the intended solutions, rather than under conditions which require analysis and reorganization to be understood and efficiently dealt with (Demetriou, 1993). Thus, they can follow complex conversations by deciphering (that is, inferring) the meaning conveyed in them, but they are not yet able to reason systematically on the basis of logical relations as distinct from the context in which they are embedded.

During primary school, children become increasingly able to manipulate multiple representations, and they become increasingly resistant to deception from appearances. Thus, they acquire considerable conceptual stability, and their knowledge of the world and the mind becomes fairly differentiated and accurate (for instance they can now differentiate between different mental functions such as attention, memory, and inference). As a result of these advancements, school children begin to reason on the basis of logical relations as such rather than automatically applying inference schemata (Moshman, 1990). However, their general attitude to problem-solving is descriptive (that is, it reflects how things are seen to be) rather than inquisitive, and they think with representations rather than about representations (which reflects an interest in the underlying properties of things and situations and their their dynamic relationships as such) (Demetriou, 1993; Flavell, 1988).

From adolescence onwards, individuals become able to view representations from the perspective of other representations (Demetriou, Efklides, Papadaki, Papantoniou, & Economou, 1993b). This opens the way for the construction of abstract or synthetic concepts that can represent the most complex and dynamic aspects of reality (Case, 1992). Thus, the adolescent's entire approach to the world is gradually differentiated from that of the child. That is, the balance gradually shifts from the description of reality to suppositions about it and to inquiry about suppositions. In other words, there is a shift in the focus of understanding from reality itself to its representation. As a result, knowledge of the mind and of the self becomes increasingly differentiated, accurate, and codified, and the adolescent can now build complex mental maps of the mind in which different mental operations and processes, such as those involved in the various SCSs, are clearly represented (Demetriou et al., 1993, Demetriou et al., 1997). Codes of mind raise inferential processes to the level of metareasoning, which enables the individual to think in reference to criteria of logical validity and adequacy (Demetriou, 1998; Moshman, 1990). The endproduct of this shift is a model-construction, a model-testing, and even a model-modeling strategic approach. This gradually generates models of the world which are recognized as such, skills for testing the models, either empirical or conceptual, and even skills for formalizing and communicating the models (Demetriou, 1998).

Later, in the years of maturity, alternative models of reality and action may be simultaneously envisaged and accepted. As a result, relativism prevails and wisdom starts to guide action (Baltes & Smith, 1990).

Postulate 4: As it Occurs at Multiple Levels, Development Has Many Faces

The view of development and mental architecture outlined above suggests that there are different kinds of developmental change. Their nature and form depend upon the system involved and the level of analysis preferred by the researcher.

At a refined level of analysis, such as hour-, day- or even week-long intervals, the mind will constantly change due to variations in the world or simply due its own functioning- which is directed either to the understanding of the world or of itself. Variations in the environment or in the condition of a system necessitates micro-adaptations in many other systems. Thus, at this refined level, development appears to be a permanent state of the system. Siegler (1995) was able to confirm this assumption by using a microgenetic method, which records development at this refined level of days or weeks. He showed that at any given period of time there is always some kind of cognitive fermentation. More specifically, at any time, some ways of thinking initially predominate and then decrease in frequency; other modes are very weak and infrequent at first but gradually increase in frequency until they dominate; others remain weak and infrequent although they are always present; and still others fluctuate between being frequent and infrequent. At this level of analysis it is difficult to specify when there is a change in developmental cycles or stages. To tell about stages may be inappropriate, since the very conept of stage presupposes a certain degree of stability, consistency, and duration. Thus, at this level development appears to be continuous rather than discontinuous.

However, when analyzed globally, development appears to occur in spurts and to result in the acquisition of new forms of understanding- as opposed to adding skills of the old kind. One example are the changes associated with representational shifts, such as the move from sensorimotor to representational intelligence or from a descriptive to a suppositional attitude towards the world. These shifts are frequently seen to demarcate the end of one developmental cycle and the beginning of another. The age phases which coincide with these shifts are usually regarded as phases during which there is an acceleration of development. This acceleration is taken as a sign of a qualitative transformation of the cognitive system, a more or less drastic reorganization of functions and processes which generates new possibilities for the thinker. And these new possibilities permit the thinker to quickly construct new abilities in various domains. Neo-Piagetians, such as Case (Case & Okamoto, 1996) and Fischer (Fischer & Bidell, in press), believe that this is the real character. They have recently used dynamic systems theory (van Geert, 1994) to show that continuity in development is a mask raised by irrelevant noise which however conceals the real nature of development which, in their view, is stage-like.

In conclusion, development seems discontinuous for certain processes at one particular level of analysis and continuous for other processes at another level of analysis. This is an important concept, because both faces of development are equally valid.

Potsulate 5: Development at Different Levels or in Different Systems of Mind Requires Different Developmental Mechanisms

Piaget believed that development was driven by a single but very powerful mechanism of cognitive development: reflective abstraction. This mechanism, which involves various processes such as assimilation, accommodation, and organization, underlies the continuous reconstruction of cognitive schemes when they are in conflict with each other or with the environment. In Vygotsky's theory, the corresponding mechanism is social scaffolding, which involves processes such as interiorization and internal speech. While these mechanisms may be valid as very general frames in which cognitive (re)construction may occur, neither is, however, sufficient to describe — let alone explain — exactly how change is effected in each of the different levels or systems of the architecture of mind or how it propagates from one level or system to another.

According to my model, different types of change take place through different mechanisms. Specifically, changes in the processing system are concerned with the flow and representation of information in the mind. When these changes occur, processing becomes faster and better able to focus on goal-relevant information and operate on larger blocks of information. Therefore, if changes in the processing system are to be transformed into functional capabilities, mechanisms such as *information search* and *selective attention,* which are concerned with information processing per se, are required.

Changes in the SCSs concern the refinement of existing operations, skills and concepts so that they become better tuned to the domain concerned, or can be integrated into larger blocks to deal with more complex aspects of the environment. These types of change may require some kind of reflective abstraction a la Piaget or some kind of social scaffolding a la Vygotsky. However, these global mechanisms are not enough to highlight what happens in an individual's mind in each of these occasions and how it takes place, moment by moment. For instance, refining an operation or concept is not the same as constructing a new concept through integration of already available ones. To refine a mental entity it must be monitored so that its components vis-à-vis the appropriate reality aspects can be mapped. To integrate two different concepts or operations requires that one be mapped upon the other to see if they are compatible and then merge them into a unified frame. Furthermore, integrating two units from within the same SCS (such as the integration of hypothesis formation with experimentation into a model construction ability that enables one to systematically build theories about the world) is not the same as integrating two units belonging to two different SCSs (such as integrating quantitative reasoning and spatial reasoning into a graph reading ability). In the first case the integration is guided by elements common to both units, such as a general conception of causality. In the second case, no such guidelines exist and integration must be constructed ad hoc in relation to the needs of the particular task. Therefore, in each of these occasions of change different mechanisms are required. I have used the terms refinement, interweaving, and bridging, respectively, to refer to these three different mechanisms of SCS change (Demetriou, 1997).

Changes in the hypercognitive system are concerned with self-monitoring, self-mapping, self-awareness, and self-regulation. In other words, these changes are concerned with the running of the mind per se and the experience this generates rather than with the context and content in which the running takes place. When they occur, changes in the hypercognitive system may have far-reaching effects in the functioning of all other systems because they may alter the terms of cognitive functioning in general. This is particularly clear in the case of *metarepresentation*, which is the primary mechanism of change in the hypercognitive system. That is, metarepresentation is considered as a process which looks for, codifies, and typifies similarities between mental experiences (past or present) to enhance understanding and problem-solving efficiency. In a sense, metarepresentation is analogical reasoning applied to mental experiences or operations, rather than to representations of environmental stimuli. For example, when a child realizes that the sequencing of the *if... then* connectives in language is associated with situations in which the event or thing preceded by *if* always comes first and that it produces the event or thing introduced by *then*, this child formulates an inference schema that leads to predictions and interpretations specific to this schema. When abstracted over many different occasions, and somehow symbolized in the mind it becomes a frame which guides reasoning by implication (Demetriou, in press). Thus, metarepresentation is the mechanism which generates general reasoning patterns on the basis of domain-specific inference patterns. It must be noted that metarepresentation goes hand in hand with *symbolic individuation*, which invests the newly generated patterns into symbols so that they can be later recalled and mentally manipulated.

Postulate 6: Intra- and Inter-Individual Variability is the Rule in Development

Postulate 3 suggests that there are changes which affect all systems and levels of mind at more or less the same age. However, the variability in the levels and systems of mind and in the forms and mechanisms of their development as suggested by the other postulates provides for variations in the development of the various systems involved in the different levels of mind both within and across individuals. For instance, all SCSs do not develop at the same rate in an individual nor is the same mechanism of change applied in the same way across different SCSs. These differences are due to many reasons. One reason is related to the fact that the dynamics of organization differ among SCSs, due to factors such as the status of kernel elements and the internal and unique constraints that define processing within each SCS. Thus, it proves very difficult to find fully equivalent formations in the concepts or problems that are supposed to belong to corresponding developmental levels of different developmental sequences. For example, the evaluation of a hypothesis based on the results of experimentation (causal-experimental SCS) and the grasp of numerical proportions (quantitative-relational SCS) are considered to be early adolescence attainments (that is, at about 12–13 years of age). However, it is difficult to see how operations in one of these abilities (e.g., comparison of evidence with an assumption) can be considered equivalent to operations in the other ability (e.g., computation of the relationships between the two numbers involved in each pair). Moreover, even if the problems are of equivalent complexity from an external point of view, they may be very different from the point of view of the thinking person herself. Subjective factors such as familiarity and individual preferences or tendencies will affect how a problem is represented and tackled (Demetriou et al., 1997), and these factors explain differences in development (Demetriou & Efklides, 1985, 1987; Shayer, et al., 1988). We must also note that differences in development are self-expansive because they channel the direction of activities. As a result, a particular difference between any two systems within an individual, or any difference between any two individuals in regard to any system at a particular time t_1, may cause further differences at a later time $t_{2,}$ which will further multiply at time $t_{3,}$ and so on (see Weinert and Helmke, this issue).

The very same reasons which generate variability in learning and development also constrain its range. That is, the operation of the domain-general systems and the dynamic relations between different modules suggest that variations in the rate of change between different processes cannot exceed certain limits at a given phase. This occurs because the capacity of the processing system sets the limits for what can be constructed at any age and the hypercognitive system provides general strategies and orientations as to how constructions can be effected.

Building Learning Environments for Hierarchical and Multi-Systemic Minds

Postulate 7: Learning Varies Across Hierarchical Levels or Systems

The assumptions on a hierarchical and multisystem mind which involves structures that deal with different types of problems in the environment bear important implications for learning. Specifically, these assumptions suggest that each of the various hierarchical levels and systems of mind may learn in ways which will make them as efficient as possible in dealing with their own types of problems. Thus, there may be different types of learning, each dependent on the level or system of mind involved. Topographically speaking, learning may be either domain-specific or domain-free.

Domain-specific learning springs from particular domains in the environment and it affects the functioning of the corresponding domain-specific modules. Thus, domain-specific learning refers to changes in the knowledge structures, processes, and skills within a module in order to better represent or cope with the elements and relations involved in the domain to which this module is affiliated. This type of learning does not generalize. Actually, generalization of this type of learning may cause problems because it may induce the person to represent and deal with other domains in irrelevant and inappropriate ways. Thus, domain-specific learning involves mechanisms such as refinement or interweaving, which ensure that the newly generated skills and concepts remain domain-specific, operationally specific, and symbolically biased. This kind of learning is called *modular learning*. Although it does not generalize across modules, it does generalize within the module affected. Specifically, it generalizes across the various components within an SCS (for instance, learning in algebra facilitates learning proportionality and vice-versa,) or across the three hierarchical levels within an SCS (that is, the level of the kernel elements, the level of the operational and processing components, and the level of knowledge and beliefs) (Demetriou, 1996, 1997; Demetriou et al., 1993).

Domain-general learning refers to changes in the knowledge structures, processes, and skills which are concerned with knowing and handling the functioning of the mind itself. This kind of learning, which is called *hyperlearning*, always involves the hypercognitive system in some way. Hyperlearning involves mechanisms such as metarepresentation and symbolic individuation, which generate, refine, and stabilize general patterns of mental action. Logical reasoning is one of the most important products of hyperlearning. By definition, therefore, hyperlearning is transferrable over different domains and, when it occurs, has immediate or delayed implications for the functioning of the other systems (Adey & Shayer, 1994).

Postulate 8: Although Distinct, Different Types of Learning Constrain Each Other

Each kind of learning obeys rules specific to it and at the same time each kind of learning may be constrained by other kinds. Specifically, modular learning in any SCS may be constrained by the condition of other SCSs. For instance, because learning in mathematics is primarily dependent on the condition of the quantitative SCS, teaching proportionality will in all likelihood fail if students do not possess the computational abilities to build relationships between two dimensions. But other systems are also involved in many subtle ways; for example, if proportionality is taught in the context of geometry, spatial thought may be required in addition to the quantitative understanding. Thus, at least some learning in a SCS may presuppose that the component required in another SCS is learned first so that it can be used for learning in our target SCS.

Modular learning may also be constrained by the condition of the general systems. Specifically, the processing system constrains three important aspects of teaching: (1) *the pace of teaching* (teaching cannot go faster than students' rate of encoding and interpreting information, because it cannot be registered); (2) *the synthesis of information* (teaching must provide only goal-relevant information, at least at the construction phase of a learning cycle, because irrelevant information may divert and hinder learning); and (3) *the volume and structuring of information* (teaching must present information at each processing step in amounts that can be represented and handled by the student).

The hypercognitive system regulates how teaching is received and processed by the student. That is, an individual's model of the mind, intelligence, and herself constrain the strategies she will employ to solve problems under different conditions, and she may channel her preferences and activities, overt or mental. Individuals can frequently, and to a certain extend, circumvent, the limitations of their processing system by employing strategies which they consider appropriate. For instance, some individuals use visualization strategies to circumvent the limitations of their processing system, whereas others use semantic integration strategies which depend on the verbal analysis of meaning. Thus, specifying the students' strategies for managing information load and semantic integration may help the teacher individualize the presentation of the same block of knowledge to different students. Moreover, the students" cognitive self-image may have more far-reaching implications in regard to their attitudes to the ongoing activity in the classroom, their study habits, and their long-term orientations and planning. For instance, students who believe that their mathematical potential is limited would be reluctant to involve themselves in activities requiring mathematics, even if their belief is not fully justified (Demetriou et al., 1997).

Hyperlearning may be constrained by the condition of the processing system or the SCSs which serve as its contents. The constraints exerted by the processing system on hyperlearning may be very different from those it exerts on modular learning. Specifically, modular learning frequently suffers because the flow of information is too fast for the processing system to follow; while hyperlearning, especially when it requires step-by-step self-monitoring, may become impossible when processing outsteps the monitoring capabilities of the mind"s eye. This latter usually occurs in tasks which involve highly automated components, such as the kernel elements or well-learned computational algorithms and skills so that ready-made response patterns or earlier successful learning at one level may hinder learning at another. This implies that for hyperlearning to become possible, the learning process would have to be slowed down so that processing steps and their outcomes evolve at a speed that would allow the mind's eye to see them. Moreover, the various SCSs are not equally amenable to self-monitoring: for example, the quantitative and the spatial SCSs are more transparent to the hypercognitive system than the causal SCS (Demetriou et al., 1997). Therefore, if one wants to facilitate the metarepresentation process with the aim to accelerate the formation of general reasoning patterns, one would have to invoke examples from SCSs which are conducive to this process.

Postulate 9: There is No One-to-One Correspondence between Individual Minds and Knowledge Structures in Education

Piaget's genetic epistemology and modern cognitive science, the current American version of Piaget's genetic epistemology (Smith, personal communication, June 1997), assume that the historical development of knowledge at the level of culture can highlight the course of individual cognitive growth. Although it is recognized that individual development and collective development at the level of the culture may not be fully commensurate, it is believed that the construction of knowledge and reasoning (and logic, which is its formal counterpart) takes place via the same mechanisms (such as equilibration or theory revision) and it proceeds through corresponding stages. This assumption leads one to expect that there should be a basic equivalence in the architecture of mind as specified here and in the organization of knowledge in education. *This is not, and it could not be, the case*. Our studies on the organization of knowledge structures in education and the individual mind clearly suggest that knowledge structures in education are broader and more inclusive than individual cognitive structures. For instance, analysis of school achievement scores reveals a "school science achievement factor" which involves performance in physics, chemistry, biology, and mathematics and which interacts with the causal and the quantitative SCS, which may be regarded as the scientific SCSs. Likewise, a "humanities factor" involves performance in language and history and it interacts primarily with the hypercognitive system (Demetriou, Gustafsson, Efklides, & Platsidou, 1992).

In my view, this lack of one-to-one correspondence between curriculum and individual structures is due to the fact that they are worked out in the context of different interaction networks and at different levels of abstraction. Individual constructions are closer to the direct object-subject interactions, because they represent the attempt of still-developing minds to understand the world on a particular occasion for a particular purpose. Collective constructions are built by developmentally mature minds through a process which is (i) governed by accepted and reflected-upon rules (e.g., the rules for mathematics or physics at a given historical era); (ii) supported and constrained by rich and well worked-out symbol systems (e.g., the language of mathematics or physics at the given era); and (iii) directed by collectively set standards and goals (e.g., the goals that shape research funding policy for mathematics and physics in a society at the given era). Thus, education, as a part of the process of development, is not simply a process of replacing individual misconceptions by implanting their corresponding collectively accepted knowledge structures or skills. On the contrary, education is-or it must be-a process that will induce the individual to use his always somehow lacking individual processing system-constrained, SCS-constrained, and hypercognitive system-constrained skills to construct for himself what has been constructed historically and collectively. This requires the construction of increasingly robust and efficient skills for handling both the lack of knowledge and the knowledge available, which sometimes has to capitalize on the present state of the architecture and dynamics of the individual mind and other times has to take place in spite of it. We have to remember that education is, after all, a process which pits the games that evolution has been masterfully playing for some millions of years against the games that human history has been clumsily playing for only a few thousand years.

Postulate 10: Classrooms Are Developmental Mixers That Incessantly Shape the Dynamics of the Developing Mind Both Intra- and Inter-Individually

I have recently argued that individual development is an abstraction which does not actually exist. That is, the changes occurring in an individual are in fact part of overlapping cycles of *co-development*. A cycle of co-development is considered to be the dynamic situation in which the changes which occur in an individual influence and are influenced by the changes which occur in other individuals in the cycle. An individual may be part of a number of cycles of co-development, such as the family, the classroom, and the peer group. Thus, we can even consider each individual as a transducer of developmental pressures from the one cycle to the other (Demetriou, 1996).

Let's take as an example a typical western classroom with about 30 students, half boys, half girls, from homes with different educational and professional backgrounds. Each of the 30 students, as a human being, possesses a mental architecture that involves all levels and systems as described above. At the same time, however, each student may differ from the others in the specific conditions and values which characterize the various parameters and systems involved in this architecture. If there were only individual student-teacher interaction in the classroom, then each individual student's condition and the teacher's proficiency would determine the outcome and dynamics of learning in the classroom. However, this is not the case. Students ask questions, call for help, make comments, or embark on activities which intervene in and variously divert the flow of teaching. Practically, this implies that at any moment the dynamics of learning in the classroom involve much more than the interaction between the teacher and the individual students. It involves all possible explicit or implicit interactions between the students themselves which may be directed or mediated by the teacher. To be more specific, to specify this dynamics one needs to take into account that there may be 30 different speeds of processing, 30 different control of processing efficiencies, etc., which exert pressures on the dynamics of teaching and learning. This dynamic is grossly captured by the following equation:

$$CD = f\, S_{i \ldots j}\, (PS_{(s,\ c,\ wm)},\ SCS_{(k,\ cm,\ kn)},\ HP_{(MI,\ MC,\ CSI),}\ ChM_{(PS,\ SCS,\ HP)}).$$

Where CD stands for classroom dynamics; $S_{i \ldots j}$ stands for the students in the classroom; PS stands for the processing system and s, c, and wm stand for the three dimensions of the procesing system, that is speed, control, and working memory respectively; SCS stands for the SCSs and k, cm, and kn stand for the kernel elements, computational processes, and knowledge within the SCSs; HP stands for the hypercognitive system and MI, MC, and CSI stand for one's model of intelligence, model of cognition, and cognitive self-image, respectively; ChM stand for the change mechanisms that regulate change in each of the various systems and levels, that is the processing system, the SCSs, and the hypercognitive system. Formidable as it might seem, this equation is much simpler than reality. This is so because there are highly important factors, such as each student's motivation and sociometric dynamics among students or among students and teachers, teacher's proficiency, and the curriculum, which are not represented in the equation. Moreover, in the equation there are no provisions for variations in the classroom dynamics over micro- and macro-time, which are of course real and extremely important.

More simply stated, the assumption is made that the response of any individual to what is going in a classroom at a particular moment in relation to a particular subject matter may somehow constrain other classmates' responses for this or for other subject matters and vise-versa. Mapping the dynamics of this co-developmental process in real classrooms has not even begun. Of course we cannot go very far forward unless we begin right now to map this and all sorts of dynamics I hinted at in this short article.

Conclusion: Constrained Constructivism

Postulate 10 + 1: Learning and Development are Constructive but Constructive Possibilities in Any System or Level in the Mind are Constrained by the Condition of Other Systems or Levels

What then is the main message of this article? I want to focus attention on the implications that this model has for our conception of the nature of development and learning. A whole mythology surrounds these two basic dimensions of the formation of the mind that we unquestionably take for granted-legacies of Piaget and Vygotsky- even when we do not accept many of the fundamental premises of their theories. According to the myth, these processes are constructive; our ten postulates above strongly suggest that the myth is not tenable. We have postulated that the mind involves multiple levels and systems which are both distinct and synergistically functioning so that development and learning in any one of them is constrained by the condition of the others. Thus, while development and learning in any SCS may be constructive to a certain extend, what can be constructed and how this is done are constrained by the condition of other SCSs, the processing system, and the hypercognitive system. Development and learning in the hypercognitive system are certainly constructive, for they represent the mind's own attempt to map and regulate itself. However, what can be mapped and how it can be regulated are largely constrained by the to-be-mapped and regulated constructs themselves. Learning in the classroom is certainly constructive because students must individually and for themeselves process, organize, and assemble any knowledge and skills offered them. However, what can be constructed by each individual student and how this is done will be constrained by the condition of the levels and systems of this student's own mind, her classmates' minds, her teachers' minds and many other factors beyond the concerns of the present article. Thus, it is time to abandon the Piagetian and Vygotskian myth of wild constructivism and consider seriously a model of *constrained constructivism*. In fact, if we are to understand how the mind is formed during development and learning we must pinpoint how development and learning in each of the system constrains and is constrained by development and learning in every other system with which it synergistically interacts and find out how we can remove or ameliorate these constraints, when necessary, and build onto them, when possible.

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