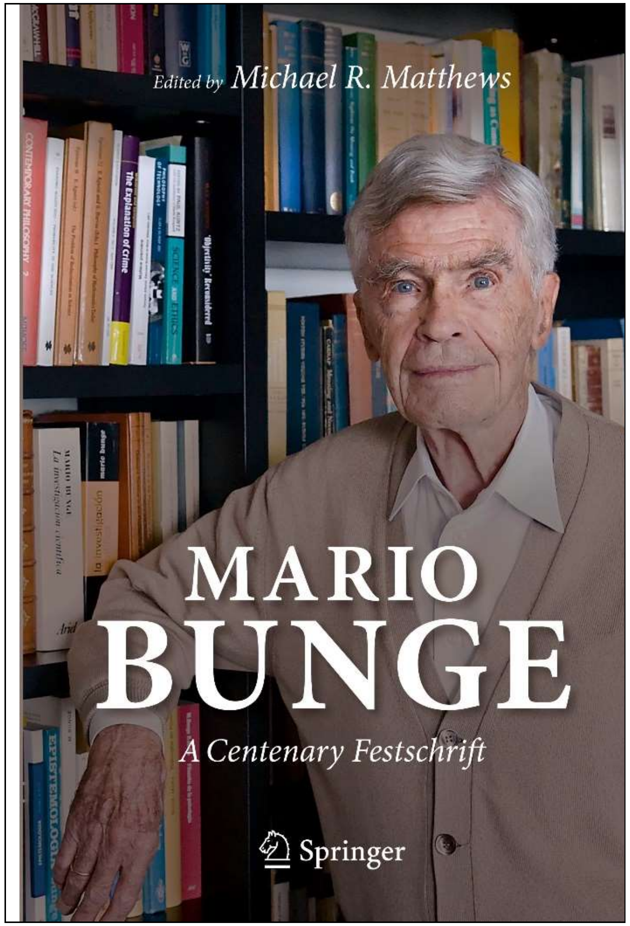
Mario Bunge
A Centenary Festschrift



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Chapter 37
Cognition and Education: A Bungean Systemic Perspective

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Abstract Everything in the universe, according to Mario Bunge, is either a system or part of a system of particular structure and function. A systemic worldview helps us make sense of the world around us and flexibly systematize how we go about constructing, retaining, and deploying all sorts of knowledge. A four-dimensional system schema is proposed to conceive a system of any sort in meaningful and productive ways, especially in experiential learning. Experiential learning can be optimized when it involves systemic transactions, between a learner and objects of learning, consciously aimed at bringing about a systemic conceptual image of each object in accordance with the proposed schema. Formal education is then supposed to provide for systemic cross-disciplinary curricula designed and deployed under systemic pedagogical frameworks, like the Systemic Cognition and Education framework, to empower students with systemic profiles for lifelong learning and success.

Making sense of the world around us and developing our knowledge about this world in meaningful and productive ways are of prime importance to humankind. Formal education is supposed to help us systematize how we go about achieving these goals efficiently while preparing us for success in various aspects of life. The success of such endeavors depends mostly on how well we infuse order in both the physical world and our mental realm. Mario Bunge's systemism offers us the best framework, from both cognitive and pedagogical perspectives, to systematize our orderly quest for meaningful and productive knowledge, sustain such knowledge in memory, and optimize the efficiency with which we may retrieve it and creatively deploy it in any situation.

Bunge's systemism is a generic worldview that cuts across cultures and academic disciplines (Bunge 1967, 1979, 1983, 2000). Accordingly, everything in this world, whether natural or human-made, physical or conceptual, is a system or part of

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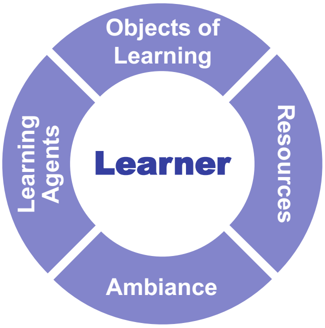
a system. Systems infuse order in the world, and help us reveal patterns in the universe, from the astronomical scale down to the subatomic scale, as well as in human body and mind. Systemic processes help us, as best as possible, systematize knowledge construction, retention, and deployment, and take full advantage of brain and mind patterns in any mental or sensory-motor process or product.

This chapter offers, in four sections, a particular perspective on Mario Bunge's systemism and how it helps us systematize both cognition and education. Our perspective emerges primarily from Bunge's philosophy and latest advances in cognitive science and especially the emerging field known as Mind, Brain, and Education (MBE) in neuroscience (Fischer et al. 2007; Knox 2016; Schwartz 2015). Section 37.1 outlines a systemic worldview whereby, in accordance with Bunge's systemism, the world within and around us is conceived as a world of dynamic systems that may interact with each other and affect the way each system is, operates, and evolves. A four-dimensional schema is proposed in this section for the construction of any system at the center of a middle-out organization of both the physical world and our mental realm, and a discussion of how to systematize our multifaceted, but especially realist-rationalist transaction with physical objects in experiential learning is presented. Section 37.2 discusses in the context of systemic cognition how such transaction involves primarily the perceptual deconstruction of any object of learning and its conceptual re-construction in two distinct but complementary and overlapping types of memory. These are working memory and short-term memory, both of which engage cerebral/mental systems of distinct functions so as to bring about learning outcomes that can be readily integrated with patterns of long-term memory. Section 37.3 subsequently argues for systemic education that explicitly and systematically: (a) aims at bringing students up with systemic profiles, (b) treats them as systemic beings with systemic minds, and (c) proceeds systemically to realize that aim in dynamic learning ecologies and in the context of cross-disciplinary curricula. The chapter concludes with a concise introduction of Systemic Cognition and Education (SCE), a generic pedagogical framework for student and teacher education of all levels that emerges from Bunge's systemism and MBE as discussed in this chapter.

37.1 A Middle-Out Systemic Worldview

We are constantly engaged in cognitive development, i.e., in the development of our content and process knowledge, and thus in changing the state of our mind (and brain) in certain respects, whether consciously or not and purposefully or not, and whether or not we are interacting with the outside world. Perhaps the most structured and most systematic cognitive development occurs under formal education, and the most meaningful development at all schooling levels occurs through experiential learning, i.e., through "transaction" – a term we borrow from John Dewey (Archambault 1964) and Mario Bunge (1967) – with real entities (objects and events included) in an appropriate learning ecology.

Fig. 37.1 Learning ecology in experiential learning



Experiential learning is about a learner's conscious and purposeful experience with one or more real world entities in a favorable learning ecology that includes, in addition to these entities (referred to hereafter as "objects of learning"), other elements that contribute to the course and outcome of the experience. In particular, experiential learning involves (Fig. 37.1):

- *A learner*, an individual student in formal education, who is engaged in the learning experience to fulfill specific purposes. In formal education, these purposes are typically set in a given curriculum in some form of content and process knowledge that students are expected to develop about, and in the context of, particular objects of learning.
- *Objects of learning*, various physical and/or conceptual entities about which, and in the context of which, the learner is expected to develop the expected knowledge (e.g., the human body or parts of it, a poem, a particular scientific concept or model).
- *Learning agents*, peers, teachers, and other people with whom the student may significantly interact during the learning experience.
- *Resources*, various physical tools, facilities, and/or information sources (textbook included) that are at the student disposal.
- *Ambiance*, classroom and school settings, other than resources, that set the overall perceptual and emotional atmosphere, and that might have direct or indirect effect on the course and outcome of the learning experience (e.g., light, temperature, student feelings).

Cognitive development takes place throughout the experiential learning experience, and the significance and meaningfulness of *learning outcomes* depend on all elements mentioned above. In particular, these outcomes depend on:

- The purpose(s) set for the learning experience.
- The sensory-motor and cognitive (mental and affective) state of the learner.
- The state of the objects of learning and all other elements in the learning ecology (Fig. 37.1).

- Transaction efficiency, i.e., the efficiency of all rational, affective, and sensory-motor exchanges that take place between the learner and all elements in the learning ecology.

Learning outcomes that the learner develops about any object of learning (denoted hereafter by O/L) at the outset of the learning experience make up a particular body of knowledge about this O/L. This body of knowledge is not a true copy of O/L in any respect or to any extent. It brings together perceived aspects which the learner focuses on in O/L and various elements in the learning ecology, along with other aspects in the learner's cognitive and sensory-motor state. Various aspects are not merely "added" together. They bring about an *emergent knowledge* about O/L with new conceptual elements in the learner's mind that cannot be attributed directly to either learner or ecology. Such emergent knowledge, as well as the entire learning experience, can best be explained by assuming the learner, objects of learning, and all other elements in the learning ecology as a set of interacting *systems* or parts of one complex system that may consist of all elements in Fig. 37.1.

37.1.1 Systemism and Systemic Transaction

This position resonates well with Bunge's "whole systemic worldview" whereby all:

> "artifacts, whether physical like television networks, biological like cows, or social like corporations, are systems. Hence... they should be examined and handled as wholes, though not as blocs but as systems". In fact, "everything, whether concrete or abstract, is a system or an actual or potential component of a system". A system, Bunge argues, is "a complex thing whose components are bound together, as a consequence of which the whole has peculiar properties and behaves as a unit in some respects... systems have systemic (emergent) features that their components lack." (Bunge 2000, pp. 148, 149)

Emergent properties, according to Bunge, are either properties that a system possesses as a whole and that are not possessed by any of its constituents, or new properties that constituents may possess because of their interaction with each other and that they would not have possessed without such interaction. A person's experience with any object, Bunge also notes, "is not a self-subsistent object but a certain *transaction* between two or more concrete *systems*, at least one of which is the experient organism. Experience is always of *somebody and* of *something*" (Bunge 1967, p. 162, italics added). The resulting knowledge is experiential in the sense that it "is attained jointly by experience … and by reason" (Bunge 1973, p. 170).

In addition to Dewey, the notion of transaction as held by Bunge is shared by numerous philosophers and cognitive scientists. For instance, Bachelard (1949) argues that what we know about the world results from a marriage between realism and rationalism. According to Johnson-Laird, "our view of the world, is causally dependent both on the way the world is and on the way we are" (1983, p. 402).

Lakoff and Johnson further argue that properties we attribute to physical objects "are not properties of objects *in themselves* but are, rather, interactional properties, based on the human perceptual apparatus, human conceptions of function, etc." (1980, p. 163).

Experiential learning, then, is primarily characterized by a purposeful, dynamic, multi-faceted transaction between a learner and object(s) of learning (O/Ls), as well as with various other elements that may exist in the learning ecology (Fig. 37.1). The transaction is multi-faceted in the sense that it involves a variety of cognitive and sensory-motor exchanges between the learner and various ecological elements, although it may involve primarily realist-rationalist exchanges with O/Ls. Cognitive exchanges engage elements and processes from the learner's content knowledge, reasoning skills (rational), and affects (motivation, emotions, interests, etc.). The transaction is realist because it is determined by the ontological state of both learner and O/Ls, and it results in "knowing" O/Ls in certain respects, and to a certain extent, the way these objects may exist in the real world. It is dynamic because it results in a temporary or permanent change in the cognitive and sensory-motor state of the learner, and possibly in the state of O/Ls and other ecological elements. Finally, the transaction is purposeful because the learner consciously aims at putting meaningful structure in what s/he perceives in O/Ls in order to make sense of these objects and develop that learner's knowledge state.

According to Poincaré (1902), things gain their significance from realist and rational perspectives only when related to each other. An entity, whether physical or conceptual, has little significance, if existing in isolation from other entities. The entity gains significance when it interacts with other entities, or when it is related, or connected to such entities in a well-defined structure. For instance, a heap of stones has little importance and utility. To borrow Bunge's words (1979, p. 3), the heap is an "*aggregate* or assemblage ... a collection of items not held together by bonds, and [it] therefore lacks integrity or unity". Stones become far more important when used in constructing a wall, and even better, a house. It is how the stones are stacked, how they are connected to each other, that turns the heap into a significant and useful structure, say a dwelling system.

A systemic perspective of the world allows us to bring cohesion and coherence to this world, as well as to our own thinking, and to understand certain aspects of this world that may not be easily conceived – and perhaps that may not be conceived at all – without such perspective. Such is the case, for example, with wholeness and holism. *Wholeness* is, for us, about the impact of any given entity or interaction (or connection of any sort) in a system on the entire system. Every constituent of the system interacts with (or is related/connected to) other constituents and somehow affects the state of the entire system. A change in any given constituent or in any given interaction or relationship between two constituents may result in a change of the entire system. Such a global impact can best be conceived and explained in the context of a system as a whole and not in terms of any clusters of relationships.

Holism is, for us, about the added value that a system as a whole brings to its constituents and the surrounding environment. A system is *holistic* in the sense that, as a *whole*, it is more than the sum of its parts. It has *emergent properties* (e.g., the shape of a house) and *synergetic functions* (e.g., dwelling) that no constituent (e.g., a stone) possessed individually before. The two holistic features may not be attributed to its individual parts and may not be fully understood and appreciated by simply breaking the system into such parts (by analysis or following a reductionist approach).

A caveat is quickly due at this point. Wholeness and holism, as we see them, do not deny the importance of individual constituents of a system within and outside the context of the system. The two systemic features do not necessarily imply a certain determinism or irreversibility in the state of system and constituents, especially not when of human or social nature. Under propitious conditions, a system may change its evolutionary course, and may as well recover from certain induced changes and return to its original state.

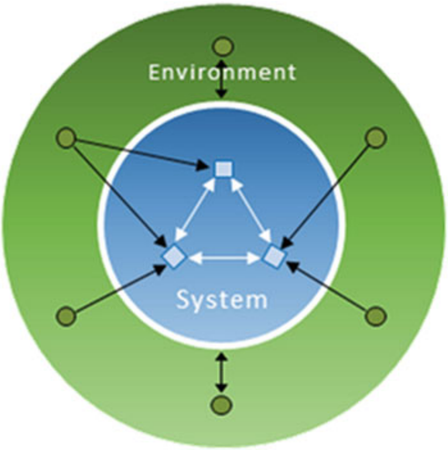
A systemic worldview is optimal for meaningful understanding of ourselves and the world around us, from the tiniest details to the big picture in any experience we might be engaged in. Research in cognitive psychology reveals that accomplished people, especially professional experts, are distinguished from other people more in the way they organize knowledge than in the type and amount of knowledge they hold in mind, and more in how they systematically deploy generic skills that cut across various professions than in how they follow idiosyncratic or profession-exclusive heuristics. System-based organization is in this respect among the most effective and efficient for structuring content knowledge, if not the optimal one. Similarly, systemic thinking, i.e., exploring the world purposely as a world of systems, and consciously constructing, retaining in memory, and deploying conceptual systems (e.g., scientific models), holds a superior standing when it comes to process knowledge (Halloun 2001, 2007, 2011, 2017a, and references therein).

37.1.2 System Schema

A system has been defined in a variety of ways in the literature, but definitions converge on the point that a system may consist of one entity (if simple) or many interacting or connected entities (if compound) confined within well-defined boundaries to serve particular purposes. The constituent entities, and thus the system, may be either physical, if consisting of material objects, or conceptual, if consisting of abstract elements (e.g., scientific models). A system, according to Bunge (1979), whether physical or conceptual, "may be said to have a definite composition, a definite environment, and a definite structure. The composition of a system is the set of its components; the environment, the set of items with which it is connected; and the structure, the relations among its components as well as among these and the environment" (p. 4). Later, Bunge (2000) added a fourth dimension, "mechanism".

The boundaries of a system are usually delineated by convenience, especially in terms of the purposes or function it is meant to serve, and so are chosen various elements and connections of interest within and outside the system boundaries

Fig. 37.2 System delineation



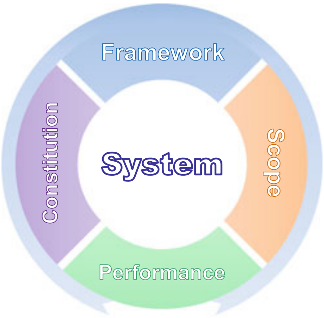
(Fig. 37.2). As shown in Fig. 37.2, the boundaries of a system and its environment (surroundings or settings in which it is embedded) are primarily determined by the purpose(s) the system is supposed to serve. The boundaries may then be conveniently delineated to account for certain entities and/or interactions (or connections) among entities of primary interest, and not others, in order to optimize what we are trying to achieve with the system (Halloun 2004/2006, 2007). Sometimes, these boundaries are delineated so that the system consists of a single entity with no internal interaction/connections, and at other times, to embody all entities of interest inside the system and end up with an isolated system with no environment to interact with. At all times, we are interested in specific interactions but not others within the system or with its environment. The arrows in the figure depict three such instances.

The two-sided arrows between system *constituents* (entities inside the system depicted with squares) indicate an interest in *mutual inter*actions or relationships between connected entities. The one-sided arrows between certain *agents* in the environment (entities outside the system depicted with disks) and constituents of the system indicate an interest only in the *action of* those agents on designated constituents, but not in the reciprocal action of constituents on agents (sometimes called reaction). The two-sided arrows between the system boundaries and agents in the environment indicate an interest in certain *mutual inter*actions between connected agents and the system as a *whole,* thus in the synergetic impact on the environment of all elements in the system acting together, and not the impact of individual system constituents.

We define a system of any sort, in both the physical world and the conceptual realm of human knowledge, in accordance with a four-dimensional schema (Fig. 37.3) that specifies the system's scope, constitution, and performance in the context of an appropriate framework (Halloun 2011, 2017a, b).

1. The *framework* of a system consists of all: (a) theoretical premises, like assumptions, principles, value system, and other ontological, epistemological,

Fig. 37.3 System schema



methodological, and axiological maxims and provisions typically spelled out in the paradigm of a professional community, and (b) ensuing strategic choices, which, along with theoretical premises, guide the specification and reification of the following three practical dimensions of a system.

2. The *scope* of the system specifies:
   (a) The system *domain*, or the field or area in which it exists and is of importance;
   (b) The system *function*, or the specific purposes it is meant to serve in that domain.
3. The *constitution* of the system specifies:
   (a) The system *composition*, its primary constituents which may be physical or conceptual entities (objects and their primary individual properties) inside the system that are relevant to its function, as opposed to secondary entities that may be part of the system but that may be ignored because we deem them irrelevant to the system function;
   (b) The system *structure*, primary connections (interactions or relationships) among primary constituents that significantly affect how the system serves its function;
   (c) The system *environment*, its primary agents or primary physical or conceptual entities outside the system, other systems included, along with their primary individual properties, that may significantly affect the system structure and function;
   (d) The system *ecology*, primary connections (interactions or relationships) between individual primary agents and constituents, and/or between the system as a whole and its environment, that significantly affect how the system serves its function (and affects the environment, if we are interested in the mutual system-environment impact).
4. The *performance* of the system specifies:
   (a) The system *processes*, dynamical actions (mechanisms or events) which constituents, and/or the system as a whole, might be engaged in, on their

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own (isolated system) and/or under external influence (of the environment), in order to serve the function of the system following specific rules of engagement;

(b) The system *output*, products, events, or any other effect (services included, when the system is, say, of social or industrial nature) that the system actually brings about, on its own or in concert with other systems as a consequence of its ecological interactions and processes, and that may fall within or beyond the scope originally set for the system.

37.1.3 Middle-Out, System Centered Epistemology

A systemic worldview allows us to systematize how we go about exploring and interacting with the world around us, meaningfully understanding this world, from the big picture in any situation we are interested in, down to the minute details and shuttling between the two structural levels efficiently and productively. It especially allows us to readily recognize morphological or phenomenological *patterns* (common regularities in space and time in the structure or behavior of different entities) that predominate in the universe at all levels, from the subatomic scale to the galactic scale, including the human mind, brain, and body, and that make our world interesting and comprehensible.

For instance, day and night recurrence and season cycles on Earth are examples of patterns, and so are the morphology and life cycles of humans and other species. The former earthly patterns are best understood in the context of our solar system (or the Earth-Sun subsystem), and the latter life patterns in the context of the species' ecological systems. Patterns also predominate in our thoughts and memories as we shall see later, and we have a natural tendency to look for patterns in the world around us, and even to rationally impose patterns on what we perceive in this world or conceive about it. A systemic perspective on the real world allows us to efficiently identify patterns of interest in this world, to rationally conceive of those patterns and to readily integrate corresponding knowledge in our memories in the manner discussed in the following sections.

As indicated in Fig. 37.4, systems occupy the middle of the rational hierarchy between a big picture (that may be a universal pattern) and specific details in a given situation. According to Lakoff (1987), humans organize their knowledge in middle-out structures whereby basic and most fundamental structures occupy the middle of the rational hierarchy between individual entities and the corpus of knowledge pertaining to those and similar entities. Systems, as we see it, are such basic structures. For example, a typical and crucial corpus of knowledge consists in science of a given theory or set of theories, and, in languages, of the various types and genres of discourse (or written text). A conceptual system in science, and more specifically a scientific model like Bohr's model of the atom, is to theory (the big picture) and concept (detail) what an atom is to matter and elementary particles. Each elementary particle at the bottom of the structural hierarchy is essential in

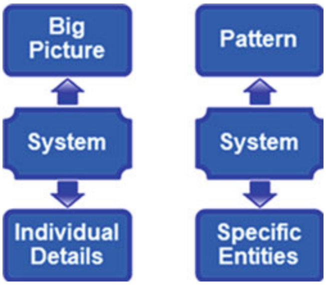


Fig. 37.4 Systems in the middle-out hierarchy between the big picture and individual details in a given situation, and between universal patterns and local or specific entities and/or connections among entities

the structure of matter at the top of the hierarchy. However, the importance of an individual particle cannot be realized independently of that particle's interaction with other particles inside an atom. It is the atom in the middle of the hierarchy and not elementary particles that gives us a coherent and meaningful picture of matter, and it is the atom that displays at best the role of each elementary particle in matter structure.

The same goes for language. A sentence is a conceptual system that stands in the middle between discourse (or text) at the top of the hierarchy and phoneme (or even word) at the bottom. The sentence gives us a coherent and meaningful picture of any type of discourse, while, through corresponding semantics and syntax, it displays at best the meaning and role of each word in discourse structure (Halloun 2001, 2004/2006, 2007, 2011).

37.2 Systemic Cognition

A systemic worldview may serve us well to understand cognition and cognitive development meaningfully, both at the cerebral and conceptual levels, and more specifically to understand what learning outcomes (LOs) are about and how they come about. Our brain is the store of our memories (LOs) and the central processor of our perceptions, thoughts, affects, feelings (emotionally generated physical sensations), and actions, and it thus governs all our learning experiences. It is the major part of our nervous system – which has been traditionally and duly called a "system" –, an intricate system that is usually divided into two complex systems, the peripheral nervous system and the central nervous system. The latter includes the spinal cord and the brain. In the following, we concentrate our discussion on conscious cognitive processes that take place in the brain during experiential learning in typical settings of formal education.

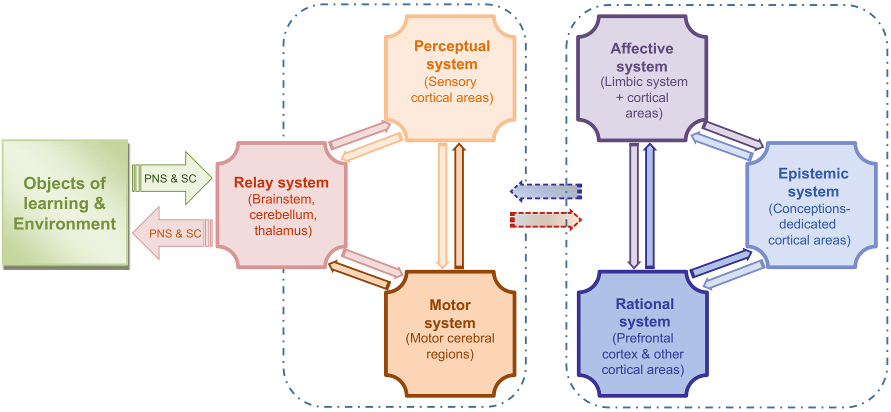


Fig. 37.5 An experiential learning model of the human brain

37.2.1 The Experiential Cognitive System

The brain is a complex system composed of billions of neurons grouped and interconnected in neural *networks*, each of specific structure and function. These networks form neural *patterns*, which allows us to conceive of them as finite sets of interconnected brain subsystems (or systems for simplicity) from either a morphological (structural) perspective or a phenomenological perspective (cognitive processes and learning outcomes). In this chapter, we concentrate our discussion on cognitive processes that are crucial for experiential learning and that highlight the importance of a systemic perspective on cognition.

From a phenomenological or functional perspective, the brain can be divided into a number of systems that may be delineated by convenience as indicated in Fig. 37.2, depending on the mental functions and processes we are interested in. Figure 37.5 shows a *model* of the brain, i.e., a *conceptual system* that provides a partial representation of how the brain is structured and operates during experiential learning. Box 37.1 outlines what we will discuss in this section about the dimensions of this system distinguished in the schema of Fig. 37.3, without rigidly structuring our discussion under the titles of these dimensions or in the order of their appearance in the box.

The experiential learning model of Fig. 37.5, like any other model, is a partial representation of the vast cerebral networks and flow of signals across the six brain systems involved in experiential learning. The model also partially represents the information exchange, via the peripheral nervous system and the spinal cord (PNS and SC), between these six systems, on the one hand, and objects of learning and the environment on the other.

The model represents a learning experience that involves input from concrete objects of learning (O/L) and the surrounding environment (Fig. 37.1). A concrete O/L may be an actual physical object or a physical representation of such object (e.g., a physical model, a computer simulation, a poster). The input detected by the senses is sent to the brain for processing, which subsequently induces memory changes in concerned areas of the cerebral cortex (mentioned between parentheses for each system in Fig. 37.5) and implies specific actions by the learner on either or both O/L and the surroundings if necessary. The input in typical classroom settings, consists primarily of a mix of visual and auditory signals to which we will return later in this section, and which do not necessarily instigate reciprocal action from the learner (passive experiential learning). The entire experience, from forwarding sensory signals to the brain, to memory change and commanding possible actions on the surroundings, is undertaken by vast neural networks spread across the entire brain.

Box 37.1: Schematic Dimensions of the Experiential Brain Model of Fig. 37.5

1. *Framework*. Premises drawn primarily from neuroscience, cognitive psychology, and the philosophy of science.
2. *Scope*. The model represents experiential learning with concrete objects of learning, and serves to describe and explain certain phenomenological aspects of neural networks in the brain regions distinguished in Fig. 37.5 so as to make sense of these objects and bring about specific learning outcomes in memory.
3. *Constitution*. The model consists of six interacting cerebral systems as shown in Fig. 37.5. The environment includes objects of learning, and possibly some other elements of Fig. 37.1, with which a learner interacts actively or passively in order to bring experiential learning to its desired ends.
4. *Performance*. Neural signals flow in specific ways across various constituents of the model so as to bring about learning outcomes in memory specified in accordance with the taxonomy of Box 37.2.

For convenience, we group these networks into six cerebral systems of six distinct broad functions that serve the purposes of our discussion of experiential learning in this section from mostly a phenomenological perspective. The systems that make up our brain model of Fig. 37.5 are the relay system, the perceptual system, the motor system, the affective system, the rational system, and the epistemic system. These constituent systems are delineated so as to reconcile the actual morphology of the brain and the taxonomy of learning outcomes (LOs) that have been developed (Halloun 2017b). This taxonomy classifies these outcomes along four multifaceted dimensions outlined in Box 37.2.

A learning experience may be triggered externally by an input from surrounding objects of learning as indicated in Fig. 37.5, or intrinsically in the absence of any external input (e.g., by a process of self-regulation). The model shown in Fig. 37.5

holds in the latter event, with intrinsic triggers substituting O/L in the leftmost box and some tweaking to the relay system if no physical interaction takes place with the environment. As indicated in this figure, once an external input is detected by the senses, appropriate neural signals are sent through the concerned parts of the peripheral nervous system (PNS) to the *relay system* of the brain, directly or through the spinal cord. This system relays somatosensory and other perceptual information, as well as motor information, to concerned parts of the brain, especially in the *perceptual* and *motor* systems respectively. It does so not in a passive manner, and not entirely on its own. It actually processes afferent sensory information (neural signals) that goes through it, and induces the *affective* and *rational* systems to get involved in focusing attention beforehand on particular sensory data emanating from O/L and surroundings, and thus in filtering perceived information. The latter two systems, as well as the *epistemic* system, get subsequently involved in processing filtered information.

The following is limited to a concise discussion of four processes that are most critical for determining how meaningful a transaction can be between a learner and O/L, i.e., how well the learner can make sense of and "understand" O/L, how readily s/he can bring about significant LOs, how long s/he can retain LOs in memory, and how productively s/he can deploy them in novel situations. Ample details about these and other processes can be found elsewhere (Halloun 2017a).

Box 37.2: Taxonomy and Systemic Assembly of Learning Outcomes (Halloun 2017b, in preparation)

Epistemic learning outcomes (LOs) pertain to various types of *conceptions* (concepts, laws, theorems, and other abstract constructs conceived to describe or explain morphological or phenomenological aspects in the physical world or mental realm), each of which may be classified in a number of categories (e.g., in science, laws comprise state, composition, interaction, causal, and quantification laws).

Rational LOs pertain to various types of *reasoning skills* (e.g., analytical reasoning, criterial reasoning, relational reasoning, critical reasoning, logical reasoning), each of which may be classified in a number of categories (e.g., analytical reasoning skills comprise surveying, differentiating, identifying regularities, describing, explaining, predicting).

Sensory-motor LOs pertain to various types of perceptual and motor skills, or *dexterities* (e.g., communication dexterities, digital dexterities, manipulative dexterities, artistic dexterities, eco-engagement dexterities), each of which may be classified in a number of categories (e.g., communication dexterities comprise listening, reading, speaking, writing, coordination of multiple representations).

(continued)

Box 37.2 (continued)

> *Affective* LOs pertain to various types of *affects* (e.g., emotions, motives, interests, dispositions, values), each of which may be classified in a number of categories (e.g., dispositions comprise open-mindedness, risk taking, autonomy, curiosity, creativity).

Learning outcomes along some or all four dimensions may come together in systemic clusters of specific functions like metacognitive controls and competencies.

Metacognitive controls include reasoning skills and affects that monitor and regulate our thoughts and actions, and especially memory formation and retrieval.

A *competency* is a specific or generic cluster of all four types of LOs. A *specific* competency helps achieving a specific task like solving a specific problem about a particular system or situation. A *generic* competency allows the deployment of attained LOs in novel situations and in the development of new LOs (and subsequently new competencies).

37.2.2 Multi-stage Filtering of Afferent Sensory Information

When a conscious learning experience is triggered externally by sensory information from O/L, the peripheral nervous system sends detected information, directly or through the spinal cord, to the *relay system* for transfer to concerned cerebral systems (Fig. 37.5). However, not all input available to our senses is sent to our brain for conscious processing. The afferent sensory information (neural signals reaching the relay system) is filtered at different levels in the brain, before and while it is being processed there.

Filtering of afferent information begins in the relay system, first in a completely automatic and involuntary manner driven by our survival needs and our instinctual emotions. A small fraction of the signals forwarded to the relay system proceed through for conscious processing in applicable systems of Fig. 37.5 (only thousands out of the millions of information bits received in any given second are ushered in to the other cerebral systems). This is the fraction we “concentrate on” or “pay attention to”, like the word or part of the word you “read” at any particular instant as you go through this text. The remaining signals (background information, including the part of the text that is not being read at a given instant) are blocked out.

Filtered information is sent to the perceptual system for processing. Meanwhile, the *affective* and *rational* systems are activated to provide *metacognitive controls* (Box 37.2) that govern the entire learning experience. Among others, metacognitive controls: (a) contribute to the filtering process, (b) sustain attention on specific perceptual information out of the already filtered information and/or redirect our senses to focus beforehand on specific perceptual data in the objects of learning, (c) determine which other systems of Fig. 37.5 will get involved in processing the information that makes it through, and to what end, and (d) regulate the formation of learning outcomes. The most critical metacognitive controls are carried by *innate* neural networks of the *affective system* that *instinctually* govern what Ekman (1992) and other psychologists call "basic emotions", or what Panksepp (1998, 2006) and other neuroscientists call "core emotions" (Gregory and Kaufeldt 2015; Panksepp and Biven 2012). Those controls may or may not allow affluent information to be processed in concerned cerebral systems, and determine, to a significant extent, the nature and quality of the cognitive and behavioral outcomes of our thoughts and actions. Some of these controls play a constructive role and allow meaningful learning to proceed, while others take over in a destructive way and may prevent any learning from taking place altogether.

For meaningful and sustained learning, metacognitive controls need to focus attention on engaging experiences that bring about emotionally significant outcomes for the individual's development. This requires the development of optimal, intuitive and almost automated means for directing attention to input that is significant to the situation we are in, and that positively and coherently engages our perceptual, motor, epistemic, and especially rational systems. Such means need to be induced and sustained by constructive metacognitive controls that originate typically in the *rational system*, and that are part of so-called executive functions handled by the prefrontal cortex (PFC) in this system, the highest level cognitive functions of the rational system.

37.2.3 Deconstruction and Reconstruction of Objects of Learning

Afferent sensory signals filtered in the relay system make up what we call a preliminary, partial *perceptual image* of the object(s) of learning (O/L). As shown in Fig. 37.6, the image is immediately analyzed in specialized areas of the perceptual system and broken down into an array of discrete and unimodal packages of perceptual information (neural signals). O/L is thereby cognitively deconstructed and a limited number of its features is retained for subsequent processing in the brain. Those features are then gradually synthesized to conceptually reconstruct O/L in specific respects that serve the transaction purposes. O/L reconstruction begins within specialized association areas (called unimodal association areas), and continues within more complex association areas (called multimodal association areas) located at the interface of various brain systems of Fig. 37.5 (Saper et al. 2000).

For illustration purposes, consider O/L deconstruction and reconstruction in a typical passive classroom experience involving, say, a teacher's audio-visual demonstration of a given phenomenon. Imagine yourself watching such a demonstration that Fig. 37.6 represents. Your eyes detect visual information that is processed in the relay system to tease out the visual constituents of the perceptual image (PI). Those constituents are then channeled to occipital cortical areas of the

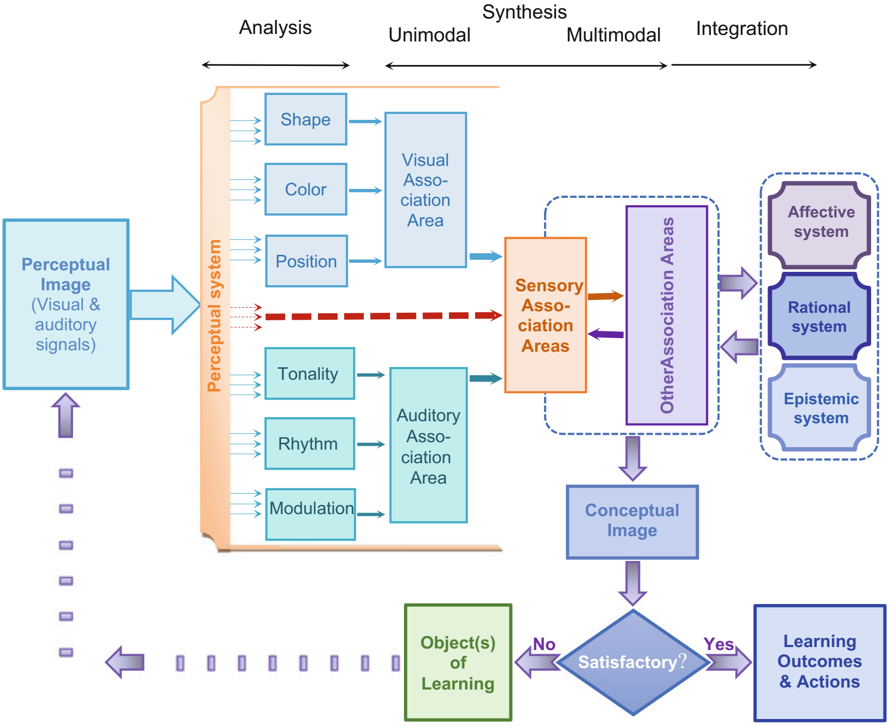


Fig. 37.6 Transaction with O/L that involves deconstruction and reconstruction of O/L

perceptual system where they are analyzed to form, say, three discrete packages of information pertaining to shape, color, and position or movement of any O/L in the demonstration.

Similarly, your ears detect auditory information (a mix of acoustic and linguistic data) that is filtered to sort out the auditory constituents of the perceptual image. Those constituents are then channeled to temporal cortical areas of the perceptual system where they are analyzed to form, say from acoustic and non-linguistic perspectives, three other discrete packages of information related to tonality, rhythm, and modulation. Similar analysis into unimodal packages takes place for the linguistic and other components of PI. Such additional analysis is represented by the thick dashed arrow emanating from the perceptual system in Fig. 37.6, and is not further discussed here to make our point with the minimum possible detail.

Once the analysis of PI ends, a gradual synthesis of the unimodal information packages begins that culminates in the formation of a conceptual image of the object(s) of learning. The three visual packages in our example are first sent in parallel along three separate neural pathways to a *unimodal* visual association area where they get integrated in a single visual package of neural signals. Similarly, the three auditory packages are sent in parallel along three separate pathways to a *unimodal* auditory association area where they get integrated in a single auditory package of neural signals. The two integrated unimodal packages (visual and auditory) are now sent, along with other unimodally integrated packages, to be integrated together in a single package within a *multimodal* sensory association area located in the posterior part of the cerebral cortex, at the interface of the parietal, temporal and occipital lobes. The newly integrated information is projected into other association areas for further processing and integration. The latter synthesis involves adduction of knowledge already in memory (i.e., neural input from various cerebral systems), and is controlled by the three rightmost systems of Figs. 37.5 and 37.6 (affective, rational, epistemic).

Analysis of the perceptual image into discrete visual, auditory, and other sensory packages in the perceptual system is automatic, unconscious and involuntary, and so is the unimodal synthesis that takes place in the corresponding association areas. Conscious and voluntary cognitive intervention (the actual transaction) begins with multimodal synthesis as indicated by the opposite arrows between different multimodal association areas in Fig. 37.6.

Multimodal synthesis takes place under the conscious control of the rational and affective systems and results in what we call a *conceptual image* of O/L (Fig. 37.6). The conceptual image is gradually constructed to fulfill the purposes originally set for the learning experience, and allow learning outcomes to be formed in memory and proper actions to be generated by the motor and perceptual systems to this end. The process is often a reiterative process that involves successive generation, analysis and synthesis of perceptual images, and gradual formation of a *panoramic conceptual image* of O/L, i.e., an image formed by successive refinement and superposition of many "shots" taken of O/L (Fig. 37.6).

The conceptual image (CI) of a given object of learning (O/L) formed by the end of a given multimodal synthesis course is evaluated by certain PFC areas in terms of its suitability to serve the purposes of the learning experience. When the evaluation outcome is not satisfactory – and usually it is not after the first PI-CI cycle – concerned PFC areas command our senses to refocus on specific aspects of O/L that help serving those purposes, and the PI-CI cycle is reiterated to refine the original CI or even replace it altogether. Reiteration continues until a panoramic CI is formed (by successive refinement and superposition) that satisfactorily helps fulfilling those purposes and that may eventually be sustained in memory.

PI faithfully, but partially mirrors the ontology of O/L in specific respects, hence the "realist" aspect of the learner's transaction with O/L. During PI analysis into unimodal bits of information, some PI details are lost. During unimodal, and especially multimodal synthesis, information is adducted from the learner's prior knowledge stored in the various cerebral systems of Fig. 37.5 and pertaining to various dimensions of the taxonomy of Box 37.2, hence the cognitive and especially "rationalist" aspect of the transaction. The emerging CI includes a blend of certain PI details (and hence of selective O/L details) and conceptual and affective details from the learner's own knowledge. In contrast to PI, CI is thus a holistic, non-positivist, non-gestalt brain-constructed image of O/L formed via the cognitive lenses of the learner. It serves to make sense of O/L and the entire learning experience.

CI *emerges* from a critical multi-faceted, but especially realist-rationalist transaction between O/L and the brain/mind, and serves *synergetic functions* that O/L alone could not serve especially from a cognitive perspective. Most importantly, CI emerges from insightful dialectics between PI and adducted knowledge, i.e., from critical evaluation and regulatory negotiations that take place externally with O/L and internally within one's own knowledge in order to continuously refine PI, and insightfully regulate CI, until the purposes of the learning experience are met with satisfaction (Halloun 2004/2006, 2017a).

A "conceptual" image (CI) of a given O/L consists primarily of epistemic components. However, CI formation, from PI unimodal analysis to multimodal synthesis, involves practically all cerebral systems of Fig. 37.5, but especially the affective, rational, and epistemic systems. During a learner's transaction with O/L, various cerebral systems are engaged and developed to different degrees; and learning outcomes may come about from all four dimensions of the taxonomy of Box 37.2.

A learning outcome (LO) is a bit of content or process knowledge that narrowly pertains to a single conception corresponding to a specific aspect of O/L (epistemic LO in Box 37.2), or to a single reasoning skill (rational LO), dexterity (sensory-motor LO), or affect (affective LO) involved in the transaction with O/L. A CI may thus consist of any number of LOs of one type or another (especially epistemic) corresponding to O/L, and may induce the formation of other LOs not necessarily corresponding exclusively to O/L (e.g., the development of differential analytical thinking). Any mention of CI in this chapter thus implies any LO developed during the transaction with a given O/L. The LO may or may not correspond exclusively to the O/L in question and may be retained temporarily or permanently in memory.

37.2.4 Memory Formation

In each PI-CI cycle (Fig. 37.6), unimodal synthesis of discrete perceptual information brought about by unimodal analysis of the perceptual image results in data that need to be retained in memory for subsequent multimodal synthesis. The lifetime of synthesized unimodal data in memory is very short in a given cycle. It may last from a fraction of a second up to a very few seconds. Such a process, and perhaps an entire PI-CI cycle, can be represented by any of the "working memory" (WM) models proposed in the literature (e.g., Baddeley 2012; Baddeley and Hitch 1974; Cowan 2014; Pickering 2006). However, WM is thought to last for a maximum of 30 s. The PI-CI cycles may be reiterated for longer than that, and a series of panoramic CIs may be needed to have a comprehensive representation of O/L in any particular experience and to form meaningful information about objects of interest. For instance, watching a classroom demonstration for some minutes, and perhaps for a good portion of a class period, requires multiple panoramic CIs, and thus multiple WM episodes to form new knowledge (LOs) about the concerned O/L, and/or refine prior knowledge about that O/L and the entire experience at hand. This of course

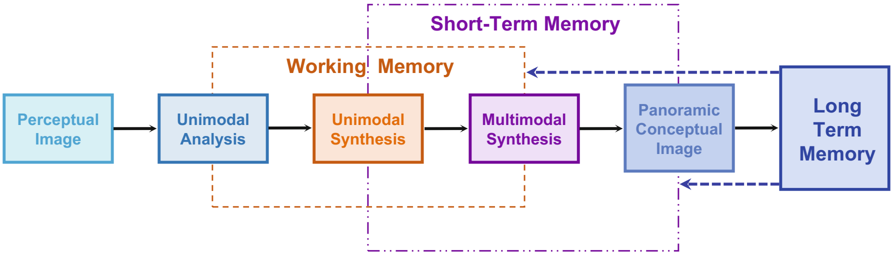


Fig. 37.7 Sequential memory formation with distinctive, but overlapping, working memory (WM) and short-term memory (STM)

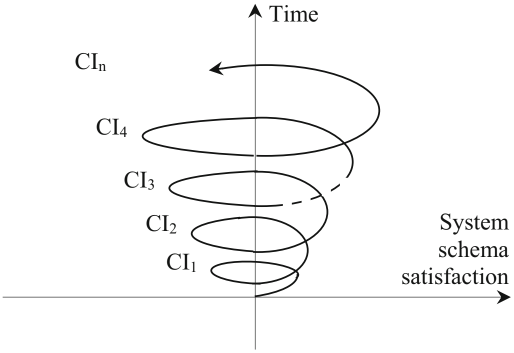
assumes that the WM models are valid for any type of knowledge distinguished in Box 37.2, and not just for epistemic, and more specifically factual knowledge with which WM is traditionally associated.

New information (CI) emerging at the end of each PI-CI cycle (or WM episode) thus needs to be temporarily retained for an entire learning experience, which may last for many minutes, and perhaps hours. Given the limited WM lifespan, emerging information has to be retained *temporarily* in a different type of memory, namely for us what we refer to as short-term memory (STM). This position is being lately echoed in the neuroscience community where some have been arguing for what they call “prioritized long term memory” to handle such temporary, but relatively long storage of information that cannot be handled by WM (Rose et al. 2016).

Short-term memory (STM) consists, for us, of information temporarily maintained in mind beyond the lifespan of WM, and processed under the control of PFC in the rational system for the sole purposes for which the information has been retained, and only for as long as these purposes need to be served. STM pertains to the formation of a panoramic CI in reiterative PI-CI cycles, and may extend well beyond the conclusion of the reiterative process depending on the need for the image in question and emerging learning outcomes (Fig. 37.7).

Reiteration of PI-CI cycles takes place under the control of particular PFC areas in the rational system. With appropriate executive functions, PFC: (a) keeps all transaction processes and outcomes focused on the specified task, (b) retains primary or relevant information emerging at the end of each cycle and deletes secondary or irrelevant information, and (c) ensures that all cycles complement each other in order to form cohesive conceptual images that bring the learning experience to the desired ends. In each cycle, metacognitive controls to which the rational system is a major contributor govern all sorts of dialectics mentioned above in order to regulate the conceptual image constructed in the preceding cycle along all dimensions of the system schema of Fig. 37.3. The regulatory reiteration in question is helicoidal in the sense that appropriate dialectics continue to enhance CI from one cycle to the next until the desired panoramic image is satisfactorily constructed (Fig. 37.8).

Fig. 37.8 Helicoidal and regulatory reiteration of PI-CI cycles



When the conceptual image (CI) is of a system object of learning that is an instance of a particular pattern, the image CI_j constructed by the end of a cycle j is developed and/or refined in the following cycle j+1 so as to better meet the system schema of Fig. 37.3, especially the system function and structure, and better reflect the pattern in question. The partially dashed line between CI_3 and CI_4 indicates that a given cycle (or WM episode) may be interrupted for any reason, but PFC would ensure that the information constructed by then is retained in STM, and would eventually bring the task back on track and ensure that it continues from where it got interrupted.

Information emerging at the end of each PI-CI cycle is temporarily retained – and processed – in memory under PFC control for as long as it is needed, and is subsequently dropped out of memory unless it makes its way to long-term memory. The lifetime of CI about a given O/L or learning experience can span from a few seconds (in WM) to a few minutes or even weeks (in STM). In formal education, the latter is the case when students retain some information (LOs) only because it is required in a given course, and not because they are convinced of its personal value, and when constructive affective and rational controls are not strong enough to induce such knowledge to be retained for good in long-term memory. Students retain required knowledge only long enough to pass a certain quiz or exam. Once the purpose is served, and the information is no longer needed, it is dropped out of memory altogether (or perhaps inhibited from being consciously remembered and retrieved). That is why, students who are able to do well on a certain quiz or exam are unable to do as well a short while afterwards on the same task. The learner is then said to have accomplished *transient learning* with LOs temporarily retained in STM. Alternatively, the learner accomplishes *sustained learning* when LOs are never dropped out, and are retained in long-term memory (LTM) instead of STM.

LTM is the resource a learner relies upon for meaningful transaction with objects of learning, whether these objects are physical or conceptual, and whether learning is experiential or not. LTM provides the cognitive lenses through which we see the world, no matter how passive and "objective" our transaction with this world is intentionally meant to be. This memory always determines what we see and what we hear, even when we encounter something or someone for the very first time in our lives. This is how, for example, we may determine that something is a plant or an animal, even when we have never seen anything like it before. Such categorization is carried out by systemic mapping of entities, properties, and especially relationships in the new experience to existing *patterns* in memory.

37.2.5 Patterning

Patterning is crucial to LTM, both at the anatomical/biological level of the brain and the conceptual level of the mind (Hernández et al. 2002; Kandel et al. 2013). LTM neural networks make up cerebral patterns (biological patterns in the brain), and connection among these networks and their activation involve patterns of neural signals flow and processing across various brain systems of Fig. 37.5. Transfer of the conceptual image (CI) of an object of learning (O/L) from STM to LTM depends to a large extent on how well CI is encoded in STM so that it can be readily integrated with LTM patterns.

Encoding of a conceptual image in neural networks begins with the unimodal analysis of the perceptual image and continues through multimodal associations (Fig. 37.6). Unimodal encoding is localized in specialized or dedicated areas of the perceptual system, and multimodal associations are spread across different cerebral regions and cortical areas, including specialized cortical areas and association areas. CI encoding begins in WM and continues in STM (Fig. 37.7). Transfer of CI into LTM, or rather its transformation from STM to LTM, its sustainability there, and the efficiency of its retrieval from LTM when needed depend primarily on how well encoded STM networks form a pattern, or part of a pattern, that can be incorporated with, or added alongside existing LTM patterns through appropriate rehearsal and consolidation processes. This all depends on: (a) the richness and depth of encoding in unimodal areas, and (b) the span of encoded multimodal networks across a variety of dedicated and association areas of the brain so as to bring about multiple conceptual representations of the corresponding O/L(s) that can be consciously negotiated with existing conceptual patterns.

Patterns predominate our conceptual realm as well as our biological cerebral networks. This realm includes content and process knowledge which we are consciously aware of and that we can communicate to, and negotiate with others. A correspondence appears to exist between cerebral patterns and conceptual patterns at the developmental level. Cerebral patterns favor conceptual patterns. The more we consciously focus on conceptual patterns in developing new knowledge, the better the chance for sustained learning, i.e., for the new knowledge to be encoded in LTM cerebral patterns.

Systems infuse order in the natural, social and conceptual worlds, and allow patterns to emerge meaningfully to and within the human mind.[1] As noted in the first section, systems are in the middle of the conceptual hierarchy between individual details and the big picture (especially a pattern) in any given situation (Fig. 37.4). As such, they are the best structured entities to ensure the coherence and efficiency of our corpus of knowledge at large, and to reveal syntactic and functional similarities and correspondence between entities of the same or different nature. When the physical world and the mental realm are conceived as interacting systems, patterns readily appear in the structure and behavior of various physical realities, from galaxies down to living organisms and microscopic matter, as well as in the structure of human knowledge, especially academic knowledge that is the object of formal education. As a consequence, it becomes easier for us to conceive the physical world and integrate conceptual learning outcomes with existing memory patterns (Halloun 2001, 2004/2006, 2017a).

37.3 Systemic Education

Bunge’s argument for a systemic worldview on all aspects of life applies particularly in education (Matthews 2012). Many reformists in education have been calling, for decades now, for “systems thinking” and “systems-level understanding” of various topics taught at different levels of education.[2] Such calls have been heeded only recently with a systemic vision captured by Goleman and Senge (2014) in their account of Social and Emotional Learning (SEL):

> we feel SEL offers only part of what students need to be well prepared for life. In today’s world of work and global citizenship, young people also need to comprehend the complexity of the problems they will face. Parallel to the development of SEL, for the past 20 years, innovative teachers have been working to introduce systems thinking into pre-K-12 schools to build a third intelligence—systems intelligence. (Goleman & Senge 2014, p. 1)

Some educators have begun integrating “systems thinking” successfully in their teaching.[3]

The implication is to call for a systemic education that explicitly and systematically adopts a generic systemic framework under which all actors (teachers included), organizations (schools and governing authorities included), mechanisms and products (curricula and learning outcomes included) are conceived as systems

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[1] See Bunge (1979), Gee (1978), Gentner and Stevens (1983), Giere (1992), Glas (2002), Harré (1970), Hesse (1970), Johanessen et al. (1999), Johnson-Laird (2006), Lakoff (1987), and Wartofsky (1968).

[2] See Garcia et al. (2014), Goleman and Senge (2014), Johanessen et al. (1999), Laszlo (2015), and Liu et al. (2015).

[3] See Assaraf and Orion (2005), Hmelo-Silver et al. (2007), Mehren et al. (2018), Rodriguez (2013), and Waters Foundation (2010).

Fig. 37.9 4P profile of a systemic well-rounded citizen

or parts of interacting systems that work in tandem to serve the major purpose of bringing up systemic citizens. In particular, such a framework that cuts across all educational levels and disciplines would: (a) aim at bringing students up with systemic profiles, (b) treat them as systemic cognizant beings with systemic minds and (c) proceed systemically to realize that aim in dynamic learning ecologies and in the context of cross-disciplinary curricula.

37.3.1 Systemic Student Profiles

Systemic education brings about learners with systemic profiles that embody professionals' patterns of success in modern life and that have at least four major general traits in common that would qualify them as 4P profiles. A 4P profile is the dynamic, constantly evolving profile of a systemic, well-rounded citizen empowered for lifelong learning and success in life, and characterized with progressive mind, productive habits, profound knowledge, and principled conduct (Fig. 37.9). The four P's are not absolute traits of a "one-size fits all" profile. They are universal "qualifiers" for distinct individual profiles which reliable research in cognitive science has constantly proven to be necessary for success – and excellence – in any aspect of life and in any era, especially our modern era (Halloun 2017a, b).

Progressive refers to an overall systemic and dynamic mindset with clear vision and determination to empower oneself and others for continuous growth and enhancement of various aspects of life. In this respect, and among other faculties, systemic education empowers every student to:

- Go after new ideas, and seek new means and methods to achieve what they are after.

- Engage in challenging tasks and take calculated risks, pursue what they are after with courage and perseverance, bounce back from any failure, and emerge with fruitful ends.
- Never follow blindly any authority, evaluate ideas critically and never accept them at face value, and appreciate and tolerate divergent points of view.
- Care about the welfare of others, whether at home, school, work, or community, and help empower them for success, even excellence in life.

Productive habits refer to practical and efficient cognitive and behavioral habits that are prone to systematic improvement and creative and advantageous deployment in various aspects of life. In this respect, and among other faculties, systemic education empowers every student to:

- Ask appropriate questions about any situation, devise flexible plans to deal with it, ascertain a plan's efficiency before carrying it out, and systematically carry out plans, evaluate them and refine them in the process.
- Identify or put together systems (in accordance with the schema of Fig. 37.3) to deal efficiently with physical or conceptual situations and identify structural and behavioral patterns within and across situations.
- Ascertain their own knowledge, consolidate their strengths, regulate their weaknesses, and resolve incoherence and inconsistency among their own ideas.
- Develop sound criteria and processes for selecting, using, and sharing appropriate resources, communicating ideas and cooperating with others.

Profound knowledge refers to a sound, essential, and coherent corpus of knowledge that readily lends itself to continuous development and efficacious and efficient deployment in various aspects of life. In this respect, and among other faculties, systemic education empowers every student to:

- Focus their content knowledge on a limited number of generic conceptions (concepts and conceptual connections) that are most meaningful for what they need to accomplish in any aspect life, and develop such conceptions coherently and efficiently.
- Maintain due balance between breadth and depth of sought after knowledge, avoid spreading thin across a wide corpus of knowledge, and revisit any acquired knowledge in novel contexts to help deepen it and broaden its scope without undue redundancy.
- Use acquired knowledge in creative ways not tried before within and outside its original scope, and go for new conceptions and processes that bring about innovative answers to certain questions or solutions to certain problems in everyday life.
- Develop generic and especially systemic tools for meaningful inception of new knowledge and comparison to prior knowledge, and for checking for internal coherence within one's own knowledge and for external consistency with what new knowledge is about in the real world and the conceptual realm of experts.

Principled conduct refers to productive and constructive conduct in all aspects of life, while intuitively driven for excellence and guided by a widely and duly acclaimed value system. In this respect, and among other faculties, systemic education empowers every student to:

- Value and convincingly implement high standards of achievement, efficiently control their negative emotions like fear and anxiety, and foster their positive emotions like motivation and interest.
- Appreciate and sustain elements of a universally acclaimed work ethic like integrity, honesty, responsibility, and accountability, and human values like honor, empathy, equity, and peace.
- Realize how individual humans' activities may have constructive or destructive ecological, cultural, and/or social impact, and contribute to constructive and sustainable solutions to related problems in their community.
- Appreciate and emulate distinguished figures behind constructive turning points in the history of humankind, objectively weigh the merits and risks on humanity of scientific findings and technological inventions, and decide whether or not such novelties should be sustained.

In systemic education, a 4P profile is translated in the program of study of any discipline or subject matter into learning outcomes (LOs) spreading across all four dimensions of our taxonomy (Box 37.2), and clustered in the form of systemic competencies required for achieving specific and generic systemic tasks, i.e., tasks pertaining to particular systems that relate to everyday life. Any such competency is then defined along all four dimensions of the taxonomy by correspondence to systemic objects of learning (O/Ls). Appropriate experiential learning tasks are explicitly designed and carried out around such O/Ls to help students consciously develop systemic conceptual images (CIs) that allow for the emergence of particular 4P traits that can be meaningfully sustained in LTM (Halloun 2017b).

37.3.2 Systemic Cognizant Students

Humans are dynamic complex systems whose minds and bodies are always involved in some form of learning. A learner's mental and physical parts and properties, and the way they relate to and affect each other internally and in relation to the learner's environment, determine the outcomes of any learning experience. In experiential learning, the nervous system is engaged in the manner shown in Fig. 37.5, along with concerned senses and other body parts. Latest research in neuroscience shows that movement of the entire body, including walking and exercising during or between class periods, facilitates sustained learning, and promotes cognitive development especially in elementary grades.[4]

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[4] See Jensen (2005), Kiefer and Trumpp (2013), Kubesch et al. (2009), Osgood-Campbell (2015), and Sousa (2010).

Embodied cognition theory "assumes that cognition is essentially carried out in the sensory and motor brain systems" in concert with related senses and body parts, and that even all sorts of abstract concepts from numbers to affects, feelings, and social concepts like desire, pity, justice, and freedom, are "embodied in perception and action" (Kiefer and Trumpp 2013). Education has thus to explicitly attend to the needs of the entire body, but especially to cognitive and developmental needs that explicitly help optimize the brain constitution and performance and the overall systemic mindset.

Sustained and meaningful learning in LTM – as opposed to transient learning in STM – favors a systemic mindset, i.e., a mind that consciously thrives in exploring the world with systemic cognitive lenses, and that subsequently sets systemic purposes for any learning experience and brings about systemic LOs. As such, and as Bunge (1967) put it, experiential learning is a transaction between two systems, the learner and the object of learning. The outcomes of that transaction are for the purpose of constructing or consolidating a conceptual system (the conceptual image of the object of learning) that may readily reveal, and be integrated with, specific conceptual patterns in the mind of the learner.

Such a systemic mindset has the advantage of bringing about the desired LOs in any learning experience efficiently and with the least cognitive demands possible, i.e., with the least processing effort possible in various brain systems (Fig. 37.5), and especially during multimodal syntheses (Fig. 37.6). It also has the advantage of optimizing the cognitive efficiency of constructed knowledge, i.e., the efficiency with which it is retrieved from LTM, and the success with which it is deployed in novel situations (Halloun 2017a).

Systemic education explicitly attends to the cognitive needs of every student and scaffolds an entire learning experience to make it efficiently meaningful and productive. In the case of experiential learning (Fig. 37.6), this extends from the formation of the perceptual image (PI) of an object of learning (O/L) to the construction, consolidation, and subsequent deployment of the corresponding panoramic conceptual image (CI). CI formation, as mentioned at the end of Sect. 37.2.3, implies sustainable learning outcomes (LOs) in LTM that pertain not only to perceptual aspects of O/Ls and are thus not solely of epistemic nature, but that may cover all four dimensions of our taxonomy (Box 37.2) and belong to all cerebral/mental systems of Fig. 37.5. All systems are duly attended to in the process, and the learner is guided to be consciously aware of what every step of the way entails, from PI to CI and from WM to LTM (Fig. 37.7), and to optimize the entire process for a systemically rich and lean CI. Beginning with the formation of PI, attention is focused on aspects that are essential for systemic learning (e.g., deep and multiple encoding/representations of primary O/L constituents and properties), and care is taken to free PI and subsequently CI from unnecessary secondary features, noise or redundancy (Halloun 2017a, b).

37.3.3 Systemic Learning Ecologies

Systemic education provides systemic learning ecologies for systemic learners to come out with systemic learning outcomes (Fig. 37.3). In experiential learning, individual students interact (transact) systemically with O/Ls, as well with other people and entities that may be in their environment (Fig. 37.1). They consciously conceive of themselves and every other person and entity they interact with as dynamic systems, and take full advantage of such systems in their details and their wholeness, and of holistic transactions among them all. Most importantly, any transaction between a learner and any entity is open to change and regulation in every respect, from framework to performance in the four dimensions of the system schema (Fig. 37.3). This, of course, requires that the learner have a voice in the process, and that this voice be heard. As such, learner and environment make up a dynamic learning ecology in which they constantly interact and cause temporary or permanent changes in each other (STM or LTM respectively for learners).

For permanent changes, especially for learning outcomes (LOs) to be sustained in a student LTM, a learning ecology needs to be sustained in certain systemic form beyond the original experiential learning experience so that the CI originally *encoded* in STM can be *consolidated* and subsequently *stored* in LTM. Consolidation takes place through sufficient deployment/rehearsal of the original CI in familiar and novel contexts, with different O/Ls, so that this image gets strengthened and enriched through multiple encoding in different multimodal association areas (Fig. 37.6). For consolidation to efficiently take place and succeed in bringing about sustainable LOs, a number of conditions need to be satisfied among the most important of which are focused attention and critical and insightful regulation.

In a systemic learning ecology, experiential learning is focused on systemic aspects of O/Ls that bring about systemic CIs with a variety of LOs (Box 37.2) sustainable in different cerebral systems (Fig. 37.5). This is made possible by the affective and rational systems that consciously control any learning experience when the two systems work constructively in tandem to inhibit any distraction and keep the entire experience systemically focused, from purpose to outcomes, and especially from perceptual image (PI) to conceptual image (CI), including the adduction of necessary information from the epistemic and other systems.

Experiential learning is characterized especially by the fact that the multifaceted transaction it involves is consciously critical and insightful. The learner's rational system, and primarily PFC with some of its executive functions, critically monitors and evaluates all PI analysis and synthesis processes and outcomes (Fig. 37.6) in WM and STM (Fig. 37.7) to ensure that they satisfy the purposes originally set for the learning experience. The rational system, and particularly PFC, also determines and monitors the adduction of appropriate knowledge from STM and/or LTM, and evaluates validity of adducted knowledge for the situation at hand. It does the same for the emergent CI and insightfully regulates that CI so that appropriate LOs may be eventually stored in LTM.

Critical and insightful regulation is made in three respects. First, a realist or empirical *correspondence* is ensured between any CI and corresponding O/L(s) so that CI properly "represents" the corresponding O/Ls for the purposes set for the learning experience, and that it is free from any noise or unnecessary superfluous or redundant information. Second, a cognitive but especially rational *coherence* is internally established between CI and LTM patterns so that subsequent LOs can be integrated with/in such patterns. Third, a rational *consistency* is externally established with professional/academic knowledge so that LOs can significantly contribute to specific 4P traits (Halloun 2004/2006).

37.3.4 Systemic Cross-Disciplinary Curricula

For decades now, research has shown that students often complete their education at any level with fragmented, compartmentalized, and transient knowledge, and educators have called in vain for focused curricula that bring about meaningful and sustained learning. The latter unheeded call, often summed up in the nineteenth century proverbial phrase "less is more", is nicely expressed in a *Science* editorial by Bruce Alberts (2012):

> Research shows that the most meaningful learning takes place when students are challenged to address an issue in depth, which can only be done for a relatively small number of topics in any school year. But the traditional process of setting standards tends to promote a superficial "comprehensive coverage" of a field, whether it be biology or history, leaving little room for in-depth learning. The curricula and textbooks that result are skin-deep and severely flawed... At all levels of schooling, we need to replace the current "comprehensive" overviews of subjects with a series of in-depth explorations. (Alberts 2012, p. 1263)

Knowledge fragmentation can best be resolved in systemic curricula, and knowledge compartmentalization can best be avoided when such curricula are cross-disciplinary.

Systemic curricula are designed under systemic pedagogical frameworks to empower students with systemic 4P profiles, mandate to this end systemic programs of study, and provide for meaningful and insightful coverage of these programs in dynamic learning ecologies that rely on experiential learning and systemic assessment. Systemic curricula do not come in one-size fits all. They are flexible enough to account for cognitive and behavioral differences among learners of the same age group, and cater for the same learner to the distinctive cognitive needs imposed by different dedicated cerebral parts where learning outcomes of different types are encoded.

Systemic programs of study are explicitly conceived around well-defined systems that allow students to efficiently grasp the big picture in a given discipline, along with pertinent details, in a middle-out approach (Fig. 37.4). To this end, every item in a program of study is explicitly conceived for the purpose of constructing and/or deploying a specific system that reflects a particular physical or conceptual pattern. Furthermore, every system is conceived with only enough essential details and connections to bring learners efficiently to the target, and ready to lend itself to the integration with some other systems within the same and other disciplines.

Systemic programs of study rely on systemic assessment for deployment in the classroom and beyond. Systemic assessment does not consider assessment as an end by itself (assessment "of" learning), but as means of learning (assessment "as" learning) and instruction (assessment "for" learning). Every assessment task is considered a learning task whereby learners do not simply retrieve ascertained knowledge from memory and deploy it exactly as it used to be stored there, but actually regulate and change retrieved knowledge in the process of adapting it to the task at hand. Teachers use the outcome to track and regulate the evolution of individual students' profiles, and to evaluate and efficiently regulate instructional means and practices, and the entire learning ecology. Most importantly, all assessments are carried out as parts of an "assessment system" whereby "different types of information are collected throughout the year using a variety of assessment tools, [and] each type of information contributes to a bigger picture of student learning" (NASEM 2017, p. 22). Each of the system components "is designed with the same set of goals in mind, even if they are used for different purposes" (*ibid*, p. 91).

Cross-disciplinarity is about building bridges among different disciplines to serve practical, systemic purposes while recognizing that no "discipline or scholarly field is an island unto itself; it is created, evolves, takes shape and responds in certain cultural, social and intellectual circumstances" (Matthews 2012). Bunge's work is an ideal case of cross-disciplinarity. He coherently synthesizes a diversity of apparently distinct and remote disciplines like physics, biology, cognitive sciences, psychology, philosophy, sociology, economy, law, and politics. Philosophy, according to Bunge, "is the study of the most fundamental and cross-disciplinary concepts and principles". His "systemics" is about a "set of theories … unified by a philosophical framework … that focus on the structural characteristics of systems and can therefore cross the largely artificial barriers between disciplines … [and thus] calls for a cross-disciplinary approach" (Bunge 1979, p. 1).

With systemic education, cross-disciplinarity is achieved when at least some systems in a given program of study are constructed with constituents coming from traditionally different disciplines, and when these systems are deployable in a variety of such disciplines, so as to bring coherence and consistency within and among disciplines, and facilitate transfer across disciplines and to everyday life.

Many professional organizations have recognized the importance of cross-disciplinarity and are working to make it a reality in practice. To this end, some leading international organizations like the International Council for Science and the International Social Science Council have even merged to bring about sustainable development at the global scale. According to McBean and Martinelli (2017), presidents of the two organizations in question that merged in October 2017 into the International Science Council, the merger:

> "will provide a new institutional context for the long-called-for convergence to become a reality". It "should help foster meaningful interdisciplinarity that begins with the joint framing of problems; ensure that all disciplines are exploiting opportunities of the digital

> revolution, including for data integration; and unify scientific communities. It will be guided in its actions by the shared vision of advancing all sciences as a global public good. (McBean & Martinelli 2017, p. 975)

37.4 Conclusion

A major implication of the discussion above is that education needs to comply, in a systemic perspective, with neuroscience-based cognitive premises in order to empower students for lifelong learning and success in life. The works of Mario Bunge and the emerging field of Mind, Brain, and Education (MBE) are seminal to this end. Systemic Cognition and Education (SCE), a generic pedagogical framework for student and teacher education at all levels, is being developed in this direction. The framework comes with cognitive tenets, pedagogical principles, and operational rules that govern devising and implementing every component of any curriculum, from programs of study to means and methods of learning, instruction, assessment, and evaluation.[5]

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[5] Related information can be found at http://www.halloun.net/sce/

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