Systemic Cognition and Education

Taxonomy of Learning Outcomes

Ibrahim Halloun
H Institute
P. O. Box 2882, Jounieh, Lebanon
4727 E. Bell Rd, Suite 45-332, Phoenix, AZ 85032, USA
Email: halloun@halloun.net & halloun@hinstitute.org
Web: www.halloun.net & www.hinstitute.org

This paper is part of a series of publications on Systemic Cognition and Education (SCE), its foundations and its applications in curriculum development and student and teacher education. SCE is a generic pedagogical framework that stems from my work on Modeling Theory in physics and science education and from reliable research in neuroscience, cognitive psychology, and education.

The first draft of the taxonomy presented in this paper appeared in 2011. The taxonomy was continuously revised afterwards based on classroom implementation and developments in the SCE framework, as well as on valuable feedback from esteemed colleagues to whom I am very grateful. A significant revision of the taxonomy was subsequently posted by H Institute in 2017. This paper offers the latest revision of the taxonomy with a more detailed discussion than before.

I would greatly appreciate your valuable feedback about this or any other SCE document at: halloun@halloun.net.

Please feel free to share the paper with interested colleagues, and to refer to it in any work. You may then gratefully cite it as:

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Systemic Cognition and Education (SCE) is a generic pedagogical framework for student and teacher education calling for system-based, crossdisciplinary curricula under a systemic worldview that embraces patterns in human brain and mind, the social realm, and the physical universe (Halloun, 2016, 2018a & b, 2019a & b; 2020a & b). According to SCE, curricula at all educational levels should be dynamic systems that bring about graduates with systemic profiles. These are the profiles of well-rounded global citizens empowered for self-fulfillment, lifelong learning, and excellence in life, who live with and for a strong national identity, and who can contribute to significant sustainable development at the local and national levels. The traits of such profiles emerge best from real life competencies that systemic crossdisciplinary curricula mandate explicitly in the form of clusters of learning outcomes spelled out in accordance with a well-defined taxonomy.

This paper introduces the SCE taxonomy in six sections and an appendix. It begins, in Section 1, with a quick overview, in the context of a systemic worldview, of systems and a system schema that serves to spell out all necessary elements of a system or any other concrete or conceptual object of learning. It then follows, in Section 2, with a brief discussion of competencies and learning outcomes in the makeup of particular profiles promoted by SCE. The multi-faceted, four-dimensional SCE taxonomy of learning outcomes is subsequently presented in Section 3, followed, in Section 4, by an outline of some specifications that outcomes statements satisfy under our pedagogical framework. Section 5 discusses how cognitive demands vary from one learning outcome to another within the same facet of the taxonomy, and subsequently how the gradual achievement of each outcome (and cluster of outcomes) can be set in five developmental stages. Section 6 discusses how our SCE taxonomy resolves certain critical issues in Bloom's taxonomy. The paper concludes with an appendix that illustrates how to set systemic programs of study in accordance with SCE system schema and taxonomy.

1. Systemism, systems and system schema

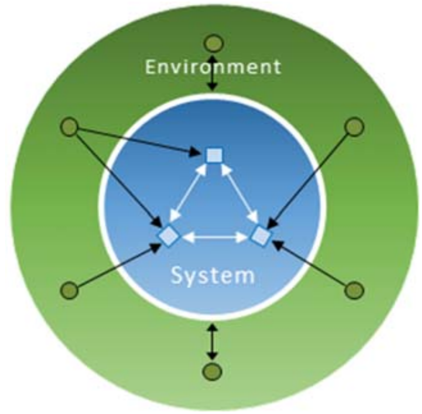
Systemic Cognition and Education (SCE) is underlined by systemism, a worldview according to which the universe consists of systems that interact with each other, just like their constituents do, in order to serve specific purposes (Bunge, 1979, 1983, 2000; Halloun, 2016, 2018a, 2019a & b). A systemic perspective of the world allows us to readily identify patterns that are of prime importance to human thought in general and education in particular, and that prevail in the structure and behavior of physical objects, from the subatomic scale to the astronomical scale, and throughout various living organisms and their ecologies, humans' mind, body, and society included. Such perspective helps us bring cohesion and coherence to the way we conceive the world, and to make the best of it and of our own selves, while we efficiently interact with all beings and objects around us (Halloun, 2004/6. 2007, 2016, 2018b, 2020b, and references therein).

In simple terms, a system of any sort, in both the physical world and the conceptual realm of human knowledge, can be defined as a set of physical or conceptual entities that interact with each other, or that are related or connected to each other, within certain boundaries in order to

Box 1. System delineation

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 set to incorporate 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, 2004/6, 2007).

Sometimes, these boundaries are set 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 the 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.

serve specific purposes (Box 1). A system is in general part of, or an instance of, a broad morphological (structural) and/or phenomenological (behavioral or operational) pattern identified in a widely accepted theoretical framework. More precisely, we define a system in accordance with a four-dimensional schema (Fig. 1) that specifies the system's framework, scope, constitution, and performance (Halloun, 2018a, 2019a & b).

1. The *framework* of a system consists of all: (a) theoretical premises, like assumptions, principles, value system, and other ontological, epistemological, 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 scope, constitution, and performance 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*, i.e., its primary constituents that may be physical or conceptual entities (objects and their primary individual properties) inside the system, and that are relevant to its function, as opposed to secondary entities that may actually be part of the system but that may be ignored because we deem them irrelevant to the system function;
    b. the system *structure*, i.e., primary connections (interactions or relationships) among primary constituents that determine how the system serves its function;
    c. the system *environment*, i.e., its primary agents or primary physical or conceptual entities outside the system, other systems included,

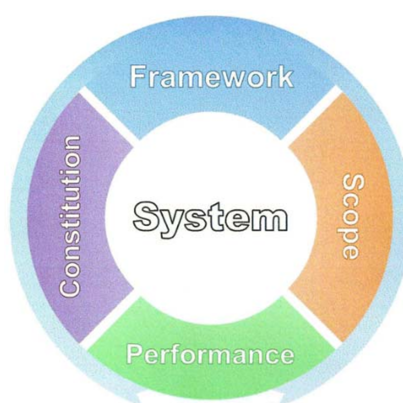


Figure 1. System schema.
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along with their primary individual properties, that may significantly affect the system structure and function;

d. the system *ecology*, i.e., 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).

It is worth stressing here that, for pedagogical purposes discussed elsewhere (Halloun, 2001, 2004/6), the composition and environment facets of the constitution dimension only list system constituents and agents respectively, and do not establish connections among them. The latter are the object of the structure and ecology facets.

4. The *performance* of the system specifies:
   a. the system *processes*, i.e., dynamical actions (operations, mechanisms, or maneuvers) which constituents, and/or the system as a whole, might be engaged in, on their 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*, i.e., 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.

A curriculum, according to SCE, is a dynamic system defined in accordance with the system schema (Fig. 1) to serve the primary function of helping students gradually develop particular profiles (Halloun, 2016, 2019a). Students develop their profiles through appropriate learning experiences situated in systemic learning ecologies also specified in accordance with the schema of Figure 1. A *systemic learning ecology* is an *experiential* ecology that provides for each student to meaningfully interact with the following entities or sets of such entities in any learning experience:

- *Objects of learning*, i.e., various physical and/or conceptual entities about which the student is expected to develop content and process knowledge as stipulated in the program of study laid down in the curriculum (e.g., the human body or parts of it, a poem, a particular scientific concept or model).
- *Learning agents*, i.e., peers, teachers, and other people with whom the student may significantly interact during the learning experience.
- *Resources*, i.e., various physical tools, facilities, and/or information sources (textbook included) that are at the student disposal.
- *Ambiance*, i.e., 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).

As discussed below, every entity mentioned above, and especially every object of learning, is conceived under SCE as a system or constituent of a system defined in accordance with the system schema of Figure 1. Subsequently, any program of study laid down in a curriculum designed under SCE, is a *systemic program of study*, i.e., a program designed around a set of physical and/or conceptual systems (objects of learning) carefully chosen in any discipline or field of study. Desired student knowledge and overall state of mind about any object of learning is detailed in such a program in the form of learning outcomes along any or all of the four dimensions of the system schema. Learning outcomes are best achieved as part of competency development so that various elements of a desired student profile gradually and coherently emerge in the course of curriculum deployment.

2. Profile, competencies, and learning outcomes

According to SCE, students may be optimally empowered for self-fulfillment, lifelong learning, and success, even excellence, at the personal and collective levels when they develop the profiles of systemic citizens. A systemic citizen is consciously aware of the importance of a systemic perspective on one-self, society, and the universe, and of the synergy and other added values that such perspective brings about (Halloun, 2016, 2020b). Furthermore, a systemic citizen is committed to carry out all thoughts and actions from such a perspective, and to bring them to constructive, high-standard ends. To serve such purposes with excellence, a systemic citizen must be empowered with a 4P profile according to SCE, i.e., a profile with *p*rogressive mind, *p*roductive habits, *p*rofound knowledge, and bound for *p*rincipled conduct (Box 2). The four broad p-traits of such a profile emerge gradually and coherently under systemic curricula through competency-based development of learning outcomes that are explicitly and systematically spelled out in accordance with an appropriate taxonomy.

A *competency* in education is what it takes to successfully accomplish a certain task or set of tasks that fall under the mandate of a given curriculum. A competency may be specific or generic. A *specific competency* sets requirements to succeed carrying out a specific task or set of similar tasks that involve one particular object of learning or set of similar or closely related objects of learning, and that traditionally fall within the scope of a particular discipline, i. e., a particular branch or area in a given academic field (e.g., classical mechanics in physics). Examples of such tasks include writing an announcement about particular events, writing a report about a particular type of experiments, solving a particular type of problems, assembling a particular piece of furniture or a particular type of electric circuits. A *generic competency* sets requirements to succeed carrying out a variety of tasks that involve a variety of objects of learning, and that traditionally make the object of the same or different disciplines. Examples of such tasks include devising and implementing a strategy that is good for solving a variety of problems in a given field; recognizing patterns and systems in one or more fields, and defining them in accordance with the system schema of Figure 1; constructing systems accordingly.

A competency, and thus any task it is about, may involve a number of objects of learning of different types. Meaningful understanding and effective and efficient use of each object of learning (hereafter denoted by O/L) in a given task (or similar tasks) require a student to develop a variety of learning outcomes about this and similar O/Ls, and these outcomes should be explicitly spelled out in the concerned program of study. A *learning outcome* (hereafter referred to by LO as distinguished from O/L, object of learning) is a unique bit of content or process knowledge, or of any other related state of mind, about a particular O/L or similar O/Ls (specific LO) or a variety of O/Ls (generic LO). It is what a student or any other learner has actually

Box 2: **4P profiles of systemic citizens** (Halloun, 2016)
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Systemic citizens are well-rounded global citizens empowered with 4P profiles for self-fulfillment, lifelong learning, and excellence in life, who live with and for a strong national identity, and who can contribute to significant sustainable development at the local and national levels.

A 4P profile is characterized as follows:

Progressive mind, i.e., an overall systemic and dynamic mindset with clear vision and determination to empower self and others for continuous growth and enhancement of various aspects of life.

Productive habits, i.e., practical and efficient cognitive and behavioral habits that are prone to systematic improvement and creative and advantageous deployment in various aspects of life.

Profound knowledge, i.e., a sound and coherent corpus of essential knowledge that readily lends itself to continuous development and efficacious and efficient deployment in various aspects of life.

Principled conduct, i.e., productive and constructive conduct in all aspects of life, intuitively driven for excellence and guided by a widely and duly acclaimed value system.

achieved, at the cognitive or behavioral levels, and sustained in memory about one particular aspect of a particular object of learning, or common to a variety of such objects. In contrast, a competency is a cluster of many LOs of different nature that pertain to various O/Ls involved in a given task and that are necessary to achieve the task in question successfully.

A specific competency requires a student to have already achieved and sustained a number of specific LOs about a particular O/L or category of O/Ls in a given discipline, while a generic competency requires generic LOs common to many categories of O/Ls within the same or different disciplines. Subsequently, students who master a specific competency can successfully: (a) carry out specific tasks, in familiar contexts, involving O/Ls about which they developed required LOs, and (b) transfer what they have learned in the process (LOs) to new tasks involving similar O/Ls in similar contexts. In contrast, students who master a generic competency can successfully: (a) carry out a variety of tasks, in familiar and novel contexts, involving O/Ls about which they developed required LOs, and (b) transfer what they have learned to new tasks involving similar and different O/Ls, in a variety of familiar, similar, and novel contexts.

Under SCE, all sorts of competencies are systemic, and so is any program of study. A systemic competency requires that any task be approached from a systemic perspective, i.e., conceived as involving interacting or related systems or components of a system specified in accordance with the system schema (Fig. 1). A systemic program of study is a program about systemic competencies that pertain to systemic objects of learning. It spells out corresponding learning outcomes along appropriate dimensions of that same system schema (cf. Appendix). LOs about any O/L or variety of O/Ls are then meaningfully achieved and sustained in long-term memory, not through isolated learning experiences involving exclusively those O/Ls, but through competency-based learning experiences that would involve other objects of learning, and thus entail additional learning outcomes along any given dimension of the system schema.

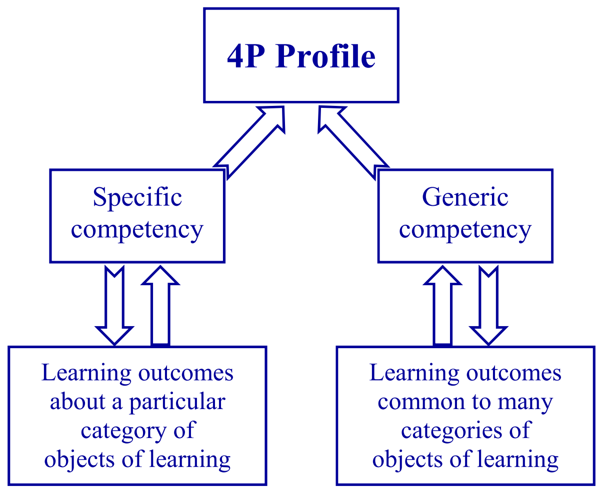

Figure 2. Middle-out, competency-based, development of learning outcomes and profile. Couples of up and down arrows between competencies and learning outcomes indicate that, although learning outcomes enter in the make-up of a competency (arrows pointing up from learning outcomes to competencies), it is the mastery of a competency that allows for meaningful and sustainable achievement of learning outcomes (arrows pointing down).

Any LO is meaningfully achieved and sustained in long-term memory following a series of well-designed learning experiences involving, among others, the related O/Ls in tasks that may require specific or generic competencies. Those experiences are intentionally situated in systemic learning ecologies (Section 1) to serve a dual purpose: (a) meaningful understanding and productive deployment of related object(s) of learning, and (b) the emergence of particular traits of a 4P profile (Box 2). A trait would then emerge in a middle-out approach from repeatedly deploying certain LOs as required by specific and/or generic competencies (Fig. 2). As such, competencies are critical to the development of both learning outcomes and profile traits, as they stand in the middle between the two in their complexity and the cognitive demands they impose.

A competency is to learning outcome and profile what an atom is to elementary particle and matter respectively. An atom is in the middle of the structural hierarchy between elementary particle (a quark or an electron) and matter (e.g., iron or wood). Each elementary particle at the bottom of the hierarchy is essential in the structure of matter at the top of the hierarchy, just like a learning outcome is to profile. However, the importance of an individual elementary 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 (Halloun, 2001, 2004/6).

Take for example the productive habit of exploring any situation from a systemic perspective. Such a profile trait emerges from mastering generic and specific competencies in systemic learning ecologies provided for in various disciplines, whether literary, scientific, artistic, social, economic, industrial, agricultural, or any other sort of discipline. More specifically, it emerges following successful, repetitive deployment of thoughts and actions (learning outcomes) entailed by any competency in a series of learning experiences that involve increasingly novel O/Ls, along with or instead of familiar O/Ls, in progressively novel contexts. Whatever the competency and the discipline might be, under SCE, any situation in any task is explored as a pool of interacting systems or constituents of a system, understanding and efficient deployment of which are determined by the extent to which are achieved certain LOs pertaining to various dimensions of the system schema (Fig. 1).

Any system of abstract or concrete nature may be typically delimited as shown in Box 1. Setting, say, the constitution of the system entails reasoning skills (learning outcomes of a particular cognitive nature) that enable us, among others, to specify entities and interactions or relations of interest. One particular LO is about discerning primary from secondary constituents and agents of the system (analytical reasoning LO). Another LO is about determining how primary constituents (and agents, if necessary) interact with each other according to specific laws or principles, or relate to each other in particular syntactical forms (relational reasoning LO).

At the early stages of development, every LO a competency entails is deployed very consciously and cautiously in any task. Following a reasonable period of drill and practice, and like riding a bicycle, we begin deploying collectively all LOs the competency entails almost intuitively so that they collectively form a *habit*. These habits become *productive* when they constantly bring about constructive results (Box 2). In our last example, following repetitive successful analysis of system and environment and identification of pertinent interactions/relations among discerned primary entities, we develop the habit of systemic efficiency. This habit drives us almost intuitively to discern primary from secondary entities based on appropriate criteria (actually implied by a judicious choice of the framework in the context of which any task needs to be carried out), and to concentrate on relationships among chosen entities that optimize the system structure and operation, and bring about subsequently the best possible output.

3. Taxonomy of learning outcomes

Any task we carry out, at or outside school, and thus any competency it requires, entails a variety of learning outcomes that pertain to one or many objects of learning and that are handled in different areas of the human brain, some of which may be specialized in certain cognitive or sensory-motor functions. For convenience purposes that actually have some ontological foundations, we have grouped various brain areas involved in cognitive or behavioral tasks in four cerebral systems that handle four distinct broad functions: epistemic, rational, sensory-motor, and axio-affective (Halloun, 2016, 2019b). Though distinct in function, in their output, the four systems are interconnected and somewhat interdependent. Each system serves its distinctive function while sharing anatomically some neural networks with other systems, and being operationally dependent in certain respects on one or more of the other three systems.

Table 1

SCE Taxonomy of Learning Outcomes

Dimension	Facet*	Description
Epistemic♣	Situated entities (Object concepts)†	Nature and composition of an object of learning (O/L) and of all primary entities (physical or conceptual objects) it is related to or it interacts with significantly, if any, –but not connections/relations among entities– and of the context (settings or environment) in which O/L and other entities are situated.
	Descriptors (Property concepts) †	Property concepts –but not connections/relations among concepts– needed to represent primary (relevant) structure and process properties of O/L and primary entities, individually and in relation to each other.
	Connections††	Relations among object or property concepts (in the form of definitions, axioms, laws, theorems, etc.), especially descriptive and explanatory relations among descriptors that express respectively "how" is an O/L state (structure and processes) and "why" this state changes or not in place and/or time. Explanation often comes with the identification of "causes", if any, that might be behind the change or absence of it, and of cause-effect relationships.
	Depictors	Symbolic and pictorial representations (alphabetic, iconic, and diagrammatic included) that may depict situated entities and related properties and connections among them all.
	Operators and operational statements	Operators (syntactic and logico-mathematical included) and rules for connecting and processing various concepts and conceptual connections, their depictors, or their physical referents.
Rational	Analytical reasoning	Exploration and analysis of the state (or change of state) of an O/L, and specification of which features (entities and their properties) are primary or pertinent and which are secondary or irrelevant for state description, explanation, and prediction.
	Criterial reasoning	Criteria-based thought processes about various aspects of an O/L in reference to the pattern it represents or it is part of, including comparison, measurement, classification, and analogical reasoning.
	Relational reasoning	Connecting appropriate concepts to establish viable morphological (constitution-related) and/or phenomenological (performance-related) relationships within and among various O/Ls and their properties, and linking up such relationships all the way to a big disciplinary picture and convergence among disciplines and fields.
	Critical reasoning	Determination and formulation of questions/problems about an O/L state; insightful inquiry and reflection about it and its merits, and about pertinent conceptions, underlying assumptions, and the entire learning ecology; anticipation of future prospects and challenges.
	Logical reasoning	Making conjectures and evidence-based arguments and inferences about an O/L and the pattern it represents or it is part of, and informed decisions and strategic choices about questions and problems at hand.

†This facet pertains, among others, to the composition and environment, but not the structure and ecology in the constitution dimension of the system schema (Fig. 1).

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Dimension	Facet*	Description
Sensory-motor	Communication dexterities	Systematic and coordinated production of concise and precise oral, kinesthetic, written, graphic, artistic, or other expression forms to depict, share, and negotiate with others various aspects of an O/L (and other entities) in accordance with sound semantics and syntax.
	Digital dexterities	Efficient and constructive use of computers, peripherals, and all sorts of ICT media (hardware and software) that help understanding O/Ls and carrying out related processes (exploration, knowledge construction, deployment, etc.).
	Manipulative dexterities	Efficient and constructive use of all sorts of physical tools and technical devices needed for various O/L processes, and that are typical of those used in school laboratories and shops.
	Artistic dexterities	Creative use of graphic arts and design, and other artistic tools, in the conception, design, and reification of necessary means for carrying out O/L processes efficiently and aesthetically.
	Ecological dexterities	Conscientious, constructive, and efficient interaction with others and the environment, and eco-conscious processes with O/L, inside and outside the classroom.
Axio-affective	Emotions (short lived)	Positive and constructive control of one's own emotions while dealing with an O/L, with sustained motivation and focused attention on aspects that fulfill personal needs and satisfaction at the conceptual and practical levels.
	Dispositions	Sustained constructive drive for successful and efficient completion of any task, an open-mind toward others' ideas especially when different from one's own ideas, and a resolve for systemism, productivity, and progressiveness.
	Sentiments (long lived) and attitudes	Sustained positive thoughts about and stance toward an O/L and concerned people, especially peers, teacher, and other learning agents, and resolve for constructive, synergetic, and respectful interaction with all learning agents.
	Ethics and values	Ethical conduct in learning tasks and beyond, by conformity to globally valued morals and codes of conduct, especially those valued by professionals in the concerned field of study.
	Civics and citizenship	Valuing any O/L, LO, and competency for personal and community merits, and in relation to one's own and others' culture and heritage, rights and duties, and sustained drive for personal and collective excellence in related tasks and beyond, in education and life.

* The choice of and within any facet depends on any given object of learning (O/L) and what needs to be accomplished with it. This choice follows then the identification, in the framework of an appropriate theory or paradigm, of: (a) the ontological nature of O/L, i.e., whether it is physical or conceptual, inert or living if physical, etc., and whether it is simple/elementary or compound/composite, (b) the pattern and/or the system O/L is about or part of, (c) the state of O/L in the context of the situation that it is in (system and/or environment, conceptual settings, etc.) and that might affect this state in constitution or performance.

♣ All five epistemic facets include semantics and syntax of corresponding conceptions.

Semantics are about the interpretation of a given conception by correspondence to its referents (i.e., what it represents in the real world or what it is about in the abstract realm) in order to make sense of it, and understand what it means, and what it is good for, in isolation of and in relation to other elements of the same nature and corresponding to the same referent.

Syntax is about the rules that must be obeyed when connecting/relating one conception to another in one form or another, and carrying out operations (including measurement and coordination of multiple representations of the same conception) that such connections entail when establishing or deploying them.

We have thus adopted in SCE a four-dimensional taxonomy of learning outcomes in concert with the four cerebral systems in question, and gave each dimension the name of the corresponding system. The epistemic, rational, sensory-motor, and axio-affective dimensions of the taxonomy are distinguished in the following and outlined in Table 1.

The *epistemic* dimension classifies various objects of learning and corresponding *conceptions* that belong to the "episteme" or corpus of content or declarative knowledge (factual and theoretical) about such objects in a given professional or academic field. A conception is the output, the conceptual product in human mind, not the process, of conceiving whatever fact, notion, or idea about a physical or abstract object of learning (O/L) or set of O/Ls. Conceptions include object and property concepts, and conceptual connections or relations among concepts. Connections may take the form of definitions, laws, principles, theorems, or other premises (theoretical statements). Epistemic learning outcomes also pertain to appropriate conceptual means or tools to depict, connect, and operate with, conceptions, as well as to corresponding semantics and syntax.

The *rational* dimension classifies *reasoning skills* needed to carry out conceptual, not physical, processes with an O/L, or set of O/Ls, and related conceptions (along with corresponding semantics and syntax). Rational learning outcomes pertain particularly to reasoning skills required for inception of and operation with conceptions in working memory, meaningful understanding and sustainable integration in long-term memory of conceptions, and their efficient retrieval from memory and productive deployment in various, but especially real life situations.

The *sensory-motor* dimension classifies *dexterities*, or physical, not conceptual, skills and perceptions needed for their own sake or the sake of developing and deploying conceptions and reasoning skills. We hereby use the term "dexterity" in a broad sense to include, in addition to manual or manipulative skills, all sorts of perceptual and behavioral operations and skills. Sensory-motor learning outcomes pertain primarily to dexterities required for taking necessary physical actions leading to meaningful and sustainable understanding of, and productive deployment of O/Ls and reification of corresponding conceptions and reasoning skills.

The *axio-affective* dimension classifies emotions, sentiments, dispositions, ethics, values, and other inter- and intra-personal *affective and axiological* factors that control our thoughts and actions in any situation. Axio-affective learning outcomes pertain primarily to those factors that control our cognitive processes, perceptions, and physical actions in formal education (*metacognitive* controls), and that bring our learning experiences to fruitful and constructive ends at the individual and collective levels.

Two issues are worth noting at this point. The first relates to the nature of our SCE taxonomy and its dimensions, and the second to the epistemic dimension.

Our SCE taxonomy is about explicit not implicit or tacit learning outcomes. *Explicit* learning outcomes, typically stored in explicit memory, are consciously developed, retrieved, and deployed. They can be clearly expressed in words and actions and explicitly communicated and prescribed to others so that they can make sense of them, ascertain their merits, and develop them properly if needed. In contrast, *implicit* learning outcomes, typically stored in implicit memory, may or may not be originally consciously developed, retrieved, and deployed. However, with practice, they come to a point where we begin deploying them *tacitly*, i.e., automatically and spontaneously without conscious rational or sensory-motor effort. This is the case, for example, of mastering a given language, especially a native language, and speaking it without any conscious recall of its semantics and syntax. This is also the case of arithmetic operations and many physical actions, like walking or driving between familiar locations, or manipulating sculpture and painting tools, that we may carry routinely, perhaps after a period of explicit development and prescriptive practice, without consciously thinking of the corresponding rules. Implicit learning outcomes deserve due attention in education, yet they form a class of their own that is beyond the scope of our taxonomy.

As for the four dimensions, we have distinguished them, and named them, in ways to be consistent with the four cerebral systems distinguished in SCE (that are concerned with both explicit and implicit learning outcomes), and to be as universal as possible along with their facets. A number of categories or *facets* are distinguished within each dimension (Table 1), and each facet is further divided into a number of subsets. For example, in the rational facet of analytical reasoning skills, we may distinguish, as discussed in section 5 below, a number of subsets (distinctive analysis skills) including survey, differentiation, description, explanation, and prediction. Different subsets impose different cognitive demands (Box 4). A subset (e.g., descriptive analysis) is delimited in our SCE taxonomy so that all corresponding learning outcomes impose cognitive demands of virtually the same level. As such, subsets are critically important from all practical perspectives in education and deserve a particular attention beyond the scope of this document. They make the object of companion papers (e.g., Halloun, 2014).

Dimensions and facets are universal and apply to all fields and disciplines. Table 1 provides for each dimension five facets that are most common to various educational/ academic fields, along with the description of each facet. The list is non-exhaustive and non-exclusive. Other facets that cut across a number of disciplines or that may be discipline-specific may still be added in any one of the four dimensions.

Some facet details and corresponding subsets are discipline specific in certain respects. The epistemic dimension is, in this respect, most affected by discipline peculiarities in traditional discipline-specific curricula. As indicated in Table 1, conceptions serve to set the characteristics of objects of learning (O/Ls) within specific settings, and to describe and explain their morphology (constitution in the system schema of Fig. 1) and phenomenology (performance, events or behavior). Individual conceptions about an O/L or a set or category of O/Ls, and especially individual object and property concepts and connections among concepts, and related semantics and syntax, are traditionally discipline specific.

Epistemic facets of Table 1, like all facets in the other three dimensions, have though been envisaged to transcend the peculiarities of individual disciplines and facilitate convergence among traditionally different disciplines. In the context of systemic frameworks like SCE, and with the focus on systemic objects of learning (O/Ls), curricula would concentrate on learning outcomes (LOs) that are most critical for bringing up epistemic *patterns* within and across various disciplines, and thus for bringing about *systemic convergence* in education (Halloun, 2018a). To this end, LOs are particularly targeted that are at the crossroads of various disciplines on the one hand, and that help bridging traditionally distinct disciplines and fields, on the other, so as to bring coherence within and across educational disciplines, fields, and curricula, and help students realize the big paradigmatic picture within and across fields.

Box 4: Cognitive demands

Every thought and action entail particular cognitive demands, i.e., mental efforts to engage and process certain conceptions and reasoning skills under certain metacognitive controls. Cognitive demands are primarily determined by: (a) the inherent complexity of the mental or physical task itself (including any possible communication about it), (b) the context in which the task is being carried out, and (c) the degree of familiarity with both task and context, as well as by (d) the nature and quality of resources relied upon (humans included), if any. In particular, cognitive demands of any task, like of any individual learning outcome (LO), pertain to mental efforts required to: (a) detect and process perceived information, if any, (b) retrieve pertinent knowledge from memory, (c) negotiate between affluent data and memory, (d) make sense of the entire experience, and (e) make necessary changes in memory. Such efforts depend primarily on: (a) the state of long-term memory, (b) the type and state of cerebral areas and cortical association areas that process perceived and retrieved information, (c) the nature and extent of back-and-forth neural processes among these areas and the subsequent load on working memory, and (d) the state and efficiency of executive functions that are carried out primarily in the prefrontal cortex, and that contribute to, and control these processes.

One last word about the epistemic dimension that is unique to our taxonomy. This dimension is meant, as noted above, to distinguish the product from the process of conceiving and deploying content or declarative knowledge (episteme). The process in question is the object of the rational dimension; it takes place under metacognitive controls (axio-affective dimension) and may involve some dexterities (sensory-motor dimension). Such distinction is crucial for setting the line between "what" certain physical or conceptual objects of learning are about and what to learn about their very existence, on the one hand, and "how" to go about learning about them and taking advantage of them in practical, especially real life situations, on the other.

Our SCE taxonomy of learning outcomes (Table 1), like any other educational taxonomy, is a classification scheme that facilitates the design of a curriculum and its deployment in all respects, from textbook authoring and resource development, to lesson planning and execution, to assessment. It is meant to respect, in certain practical respects, brain anatomy and operation, but it should by no means be interpreted as if our brain might at any time process exclusively one type of LOs without the other three. Any task, no matter how simple it might be, implicates a competency that entails all four types of LOs. However, the task might involve some LO types more than others, and some LOs might be more complex than others of the same or different types and might impose more cognitive demands than others (Box 4). Thus in education, we need to identify competencies and cognitive demands (and obstacles) that learning about a given O/L imposes, so that we know what learning experience in what ecology is most appropriate for meaningfully achieving all related learning outcomes. We also need to monitor with proper "control of variables" individual students' engagement in such experiences, and pinpoint as precisely and narrowly as possible what LOs each learner actually achieves as a consequence. This is where taxonomy becomes crucial, and especially the way learning outcomes are stated.

4. Learning outcomes statement specifications

A *learning outcome* (LO) is what a student has *already reified or achieved* at a given point, in meaningful and measurable ways, about a given facet of the taxonomy, or a specific aspect of the facet, by correspondence to specific object(s) of learning (O/L) or a variety of such objects. Unlike a competency that involves a variety of facets from all four dimensions of our taxonomy, a learning outcome pertains to one facet, and only one facet, in one particular dimension of our taxonomy. More precisely, it is about one specific subset of a given facet as discussed in the following section, and thus about one specific conception (*epistemic* LO), reasoning skill (*rational* LO), dexterity (*sensory-motor* LO), value (in the broad axiological sense) or affect (*axio-affective*, and especially metacognitive, LO), pertaining to the O/Ls in question.

A learning outcome is specified and stated or expressed as deemed beforehand necessary and suitable for certain OLs and competencies, i.e., before students are observed in action to determine what they have actually achieved, and it may be refined afterwards. This practice of stating an LO as *desired* or *expected* is crucial in order to design and deploy learning experiences that are appropriate for students to reify (achieve) that LO, and to reliably assess the extent to which each student has actually reified the LO. The assessment in question results in an *inference* about the LO state in a student's mind (or body) from the student performance on specific tasks, and never in an actual snapshot of the LO. The inference reliability is primarily function of the quality of indicators chosen and associated à priori with particular scales that are often task dependent. A task can be simple enough to target only that particular LO, or it can be involved to target a given competency in relation to a particular O/L (a system or part of a system) or set of O/Ls, and thus to entail simultaneously a number of distinct LOs in distinctive aspects of the task.

One may thus distinguish between a desired LO and an achieved LO. The efficacy of instruction would then be measured by the extent to which the achieved LO matches the desired LO. Our SCE taxonomy is about desired LOs, but it equally applies to classifying achieved LOs. The following discussion pertains to the statement of desired LOs (hereafter referred to as learning outcomes or LOs). The reader may though readily notice that discussed specifications equally apply to achieved LOs.

The statement of any LO must stipulate what exactly students are expected to demonstrate while carrying out a task of any sort. It should do so in a form that would be unequivocally interpreted by all concerned actors (teacher, student, author, etc.) so that they would eventually make virtually the same "inference" about the extent to which a student has reified the LO. To this end, the statement of any LO must have, among others, the following specifications:

Single faceted: The LO statement, like the outcome itself, must pertain to one facet, and only one facet, of a particular dimension of the taxonomy, and preferably, especially in designing assessments, to one particular aspect or subset of a given facet.

Transparent: The LO must be stated so as to readily reflect what dimension of the taxonomy it is about (epistemic, rational, sensory-motor, or axio-affective), and to what extent students are expected to achieve (or demonstrate to have already achieved) a given facet in the dimension in question, or a particular subset of the facet, be it a conception, a reasoning skill, a dexterity, a value or an affect.

Compact: The LO statement must concisely and precisely spell out what students are actually expected to achieve about the corresponding facet/subset.

Self-contained: The LO statement must contain all the information needed for a teacher (or any other concerned actor) to know what exactly students are expected to achieve about the facet, and to determine what indicators to look for in student performance with related O/Ls, and along what scale, in order to ascertain the extent to which the outcome has actually been achieved.

Clear: All concerned actors must be able to interpret the LO statement unambiguously and objectively, all the same way, and agree on the nature of tasks needed to help students achieve the outcome and/or reliably assess student achievement of that outcome.

Reasonable: Students are competent enough to achieve the LO as stated, and teachers can manage students' learning experience within the confinement of existing curricula and school settings, or with affordable changes therein.

Measurable: The LO must be measurable as stated, readily lending itself to an appropriate rubric with appropriate indicator(s) and scale that allow reliable assessment of the extent to which individual students have actually achieved the outcome.

Integrable: The LO must readily lend itself to blend coherently and with no redundancy with other LOs it is meant to complement, especially when entailed by a given competency, and defined in a systemic perspective in accordance with the schema of Figure 1.

Profile germane: The LO must be clearly related to a specific trait of the target profile (a 4P profile of Box 2 in our case), and should readily imply the level at which that trait has been achieved or is expected to be achieved.

Framework consistent: The LO must be well situated within the adopted pedagogical framework (SCE in our case), from statement to implementation.

Transportable: The LO is viable and can be achieved, even if in certain respects and to a certain extent, under any pedagogical framework other than the one under which it has been originally conceived and stated.

The appendix illustrates how to state learning outcomes that meet, though in part, the specifications mentioned above. It does so with the outline of a particular system that shows how programs of study can be stipulated in systemic curricula in accordance with our system schema (Fig. 1).

5. Cognitive demands and development

A learning outcome (LO) is always “achieved”, i.e., meaningfully encoded, retained, consolidated, and sustained in long-term memory (LTM), by correspondence to certain object(s) of learning (O/L). Achievement of any LO thus involves complex cognitive processes (a mix of epistemic, rational, and axio-affective), and, when in experiential settings, behavioral or sensory-motor processes, that impose particular cognitive demands on the cognizant person (Box 4). Such demands may vary from one LO to another, even if they belong to the same facet in the same dimension of our SCE taxonomy.

Take for example the rational facet of analytical reasoning skills. In this facet, we distinguish a number of subsets (distinctive analysis skills) including survey, differentiation, description, explanation, and prediction (Halloun, 2014). Survey is about the comprehensive identification of the features (constituents and their properties) of a given object of learning (or any situation involving this O/L and more), without ascertaining the relative significance or importance of these features in a given task. Differentiation, however, is about distinguishing between primary and secondary features, i.e., and respectively, between O/L features that are pertinent to what we are interested in about the O/L and features that are not and that can be ignored as a consequence. Description is about identifying primary morphological and/or phenomenological features that pertain respectively to the O/L constitution and performance dimensions in our system schema (Fig. 1), and that define the state of O/L, i.e., that tell “how” it looks and behaves at a given point of space and time. Explanation is about identifying primary causes of the O/L structure or behavior, if any, i.e., about telling “why” the O/L is constituted and performs as it does. Prediction is about how the O/L constitution and/or performance may evolve in the future under certain conditions, or about how it used to be in the past (post-diction) before it got to the current state. One can readily realize that differentiation imposes more cognitive demands than survey, and that increasingly more cognitive demands are imposed as we go from description to explanation, and then prediction.

One may thus identify a certain cognitive hierarchy among various LOs depending on the cognitive demands they impose. In our example about analytical reasoning, survey is the easiest to carry out and comes at the bottom of the hierarchy among analytical reasoning skills, while prediction comes on top. A similar cognitive hierarchy may be defined in terms of cognitive demands among various subsets in any facet, but not necessarily among various facets in a given dimension or among various dimensions in our SCE taxonomy (Table 1). Under SCE, we assume no absolute or universal cognitive hierarchy among the four dimensions of our taxonomy or among the five facets in any dimension. We also assume no developmental sequence among facets and dimensions, i.e., no chronological order in which they come about in the profile of a given person as s/he evolves with age and education.

All we assume in connection with cognitive hierarchy is certain “maturity” order among certain subsets within any given facet. For instance, each of the five analytical reasoning subsets distinguished above evolve with age and education. However, the onset and subsequent mastery of some subsets may precede others because: (a) they have less cognitive demands, and (b) the neural networks that process them in the brain are developed to the needed level earlier than other networks because of biological constraints (neurons anatomy and connections) and/or practical experience (nature-nurture complementarity). As such, survey skills usually mature before differentiation skills, and description skills before explanation and prediction skills.

In SCE, we hold that each subset in any facet, and, subsequently, that each learning outcome evolves gradually and progressively to any desired level of cognitive or behavioral maturity. The same holds for any set of LOs, competency included, pertaining to common referents or common objects of learning, systems and patterns included. Such gradual evolution may be conceived in consecutive developmental stages delimited with respect to specific criteria. In SCE, we delimit stages in terms of the following provisions mostly related to certain cognitive demands (in relation to our system schema) and aspects of the learning ecology:

1. The domain of a learning outcome or the array of O/Ls (referents) to which the LO pertains.
2. The connections of the given LO with other LOs, especially for sustainable integration in long-term memory (ultimately in the context of a given pattern and/or system).
3. The level of dependence on learning agents, i.e., of assistance required from teacher, peers, and other people, to succeed in a given task.
4. The level of dependence on information sources, namely textbooks and related paper and digital references.
5. The degree to which the learner can work with and assist peers in developing the LO in question.
6. Metacognitive controls that govern or drive the development process, especially motivation and self-satisfaction.

Accordingly, we distinguish five developmental stages outlined in Table 2 for any LO (or set of LOs, competency and system included), whether a conception in any discipline or educational field, a reasoning skill, a dexterity, a value (in the broad axiological sense) or an affect. At the early stage of development, the stage of initiation, a learner partially achieves the LO in the context of one specific referent or a restricted set of referents. Gradually in the following two stages, the learner achieves the LO, first somewhat satisfactorily in limited contexts (inception), and then to the desired maturity level (emulation), but still exclusively in the original theoretical and practical contexts in which the LO was developed under guidance, and almost entirely with external locus of control. Subsequently, the learner begins gradual transcendence of the original contexts and control to extrapolate the LO in creative ways in novel contexts (production), and ultimately in innovative ways in self-designed contexts to serve entirely new purposes (invention).

The same stages apply to any facet or dimension of our taxonomy, to any competency, and to the entire profile that students are expected to develop under any curriculum. As a learner evolves from the primitive stage of initiation to the ultimate stage of invention, any LO (or set of LOs) is gradually developed as follows in terms of the six provisions considered above:

1. The array of O/Ls (referents) successfully inducted in the LO domain gradually expands from one particular referent or one particular and restricted set of referents relative to which the LO was originally introduced in a particular discipline (Stage 1), to a wide array of similar referents in the same discipline (Stage 3), and then to completely different referents in this and different disciplines (Stages 4 and 5). Various O/Ls are maintained in their original state through Stage 4 beyond which the learner extrapolates the LO to conceive and implement possible changes in the constitution and performance of those O/Ls or to invent entirely new objects.
2. The number and complexity of connections established with other LOs gradually increase from a limited and loose number of LOs, mostly of the same nature and in working or short-term memory in the first stage of initiation, to a progressively wider and integrated mix of LOs of different nature (in LTM) in the context of an increasing number of systems and a pattern or more of increased thoroughness (Differences between different types of memory are discussed in Halloun, 2016 and 2019b).

3. The level of dependence on learning agents gradually decreases across stages so that the learner becomes fully autonomous by the time s/he reaches Stage 4 and an innovative initiative taker in Stage 5.
4. The level of dependence on original information sources gradually decreases through Stage 3, beyond which these and new sources are no longer sought for mere LO development and deployment in its originally delimited scope, but to broaden this scope in domain and function.
5. The learner might look up for peers in the first three stages mostly for soliciting their assistance or cooperation, and in subsequent stages to provide guidance and assistance to struggling peers, or to cooperate with competent peers on equal footing for creative and innovative purposes.
6. LO achievement is originally authority driven with the sole motive of satisfying such authority and curriculum requirements, but by the time Stage 3 is reached and LO merits are appreciated, intrinsic motivation and relative self-satisfaction with no absolute gratification begin driving the learner in creative and innovative paths.

A learner reification or achievement of a given LO (or set of LOs) may or not evolve to the same stage with respect to all six provisions in Table 2 at any point of LO development. Furthermore, learners in the same cohort of students do not necessarily all evolve to the same stage with respect to any of the distinguished provisions at a given point of instruction. At a given point of the evolution process, a learner may reach a particular stage with respect to any one of the provisions, and lag behind or be ahead, usually by one stage, with respect to one or more of the other provisions. The status of the LO in the learner's profile may then be defined by an appropriate 6-point matrix showing the distinctive stage reached with respect to each provision, or approximated by a median stage around which hover all six provisions.

The five developmental stages of Table 2 are grounded in seminal neuroscience findings, in the last decade or so, about the natural cognitive development process (Halloun, 2016 and references therein). These findings point out that learning about any O/L begins mostly in the perceptual areas of the cerebral cortex that are heavily context dependent, with: (a) short range connections established among various cortical areas, and (b) LTM formation (knowledge encoding and consolidation) and accessibility for knowledge retrieval entirely controlled by the hippocampus. All this constrains learners' achievement and deployment of any LO to familiar contexts that involve the same O/L or similar ones, and that impose relatively low cognitive demands. Such is the case with our first three stages, initiation, inception, and emulation. Subsequently, and always according to neuroscience, learning evolves to engage conceptual areas of the cerebral cortex that are relatively context independent, with long range connections weaved among engaged areas, and LTM accessibility primarily controlled by the pre-frontal cortex instead of the hippocampus. All this allows learners' extrapolation of any LO to novel contexts with relatively high cognitive demands. Such is the case with our last two stages of production and invention.

Table 2
SCE developmental stages

Provision / Stage	Domain	Connection with other LOs	Learning agents	Information sources	Engagement with peers	Metacognitive drive
1. Initiation or primitive achievement	Inarticulate LO retention in working memory, but not yet in long-term memory* (LTM), with partial deployment success in the context of the original O/L and a few similar objects in familiar situations.	Connection in working memory with some closely related LOs, mostly of the same nature, with possible temporary integration in short-term but not long-term memory (LTM).	Dependence on others to develop the LO (understand and deploy), mostly by rote and only in certain respects.	Total dependence on textbook and other references, in addition to learning agents, for realizing what the LO is about and how it can be achieved.	Discourse with peers limited to what the LO could possibly be about.	Resignation to teacher and curriculum authority who mandate the LO and might promote it as a necessity to satisfy certain academic needs (mostly passing exams in traditional settings).
2. Inception or limited achievement	Articulate LO retention in short-term memory (STM), but not yet in LTM, with deployment success limited to the context of the original O/L and similar objects in familiar situations.	Integration in STM with closely related LOs, of the same and different nature, with the potential of sustainability in LTM.	Assistance often needed to develop the LO in all respects, and still mostly by rote.	Frequent recourse to textbook and other references to develop the LO, yet only partially and by rote.	Working with peers under the assistance of higher learning agents to undertake certain tasks without necessarily succeeding.	Motive induced mostly by the desire to satisfy others and curriculum requirements, and by some primitive appreciation of the inherent LO merits.
3. Emulation or contextualized achievement	LO achievement (sustained in LTM and successfully deployed as required) by correspondence to a number of O/Ls in the same domain within a given discipline, including one appropriate system or more, in accordance with the system schema, and in familiar situations or new but similar ones.	Integration, and sustainability in LTM, with closely and distantly related LOs of the same and different nature to consolidate one particular pattern.	Little guidance or support, if any, for meaningful understanding of what the LO is about and for in the specified scope, and successful completion of related tasks.	Occasional recourse to various resources to identify appropriate pathways for achieving the LO as required.	Working with peers, with little guidance, if any, and possibly assisting those in need for help to achieve the LO as required.	Motivation driven by the appreciation of the inherent merits of the LO, and a determination to satisfy personal needs and ambitions to a certain level of gratification.

Stage \ Provision	Domain	Connection with other LOs	Learning agents	Information sources	Engagement with peers	Metacognitive drive
4. Production or creative achievement	LO extrapolation to new O/Ls in novel situations that may be totally different from familiar ones, LO sustained LTM integration with other system related LOs in accordance with the system schema, and transfer to new domains within the same and different disciplines.	Integration, and sustainability in LTM, with closely and remotely related LOs of the same and different nature to consolidate one pattern or more in a given paradigm.	Total autonomy in deploying the LO within the specified scope, occasional guidance sought for LO transfer to new domains.	Occasional recourse to various resources, mostly for LO transfer to new domains.	Leading the work with peers to help them achieve the LO as required and beyond.	Motivation driven by the determination to take the LO to new horizons and a passion to master and expand one's own competencies beyond any level of gratification.
5. Invention or innovative achievement	LO extrapolation to change related O/L features, design and develop new systems or system features, and deal with entirely novel situations within the same and different disciplines.	Integration, and sustainability in LTM, with closely and remotely related LOs of the same and different nature to consolidate a number of patterns and induct a new one with the possible extrapolation to a new paradigm.	Autonomous drive for widening the LO scope and pushing its function into innovative directions.	Recourse to appropriate resources for coming up with and carrying out innovative ideas.	Taking the initiative to engage qualified others in coming up with and carrying out innovative ideas.	Motivation driven by the lack of gratification (the sky is the limit) and a passionate drive to open new horizons.

* The three different types of memory, working, short-term, and long-term, are discussed elsewhere (Halloun, 2016 and 2019b).

6. SCE and Bloom's taxonomy

Bloom's taxonomy of educational objectives involves three "domains": cognitive, psychomotor, and affective (Bloom, 1956). This taxonomy, in its original and various revised forms, comes with a number of critical issues, especially in its cognitive domain that is the most prevalently applied domain in education. Our SCE taxonomy helps resolving such issues, especially the mix up between content and process knowledge in the six "categories" distinguished in Bloom's cognitive domain and the unwarranted developmental hierarchy presumed throughout these categories.

Until the turn of this century, the following six categories were distinguished (and continue to be so by some) in Bloom's cognitive taxonomy: knowledge, comprehension, application, analysis, synthesis, and evaluation. A number of revisions were proposed since, perhaps the most prevalent of which distinguishes the following categories: remembering, understanding, applying, analyzing, evaluating, and creating (Anderson et al., 2001). A developmental hierarchy is presumed across these categories in various versions as indicated in Figure 3. The knowledge category (or the remembering alternative) comes at the bottom of the hierarchy as the most primitive, and the evaluation category (or the creating alternative) comes on top as the most involved. The top three categories (analysis, synthesis, and evaluation, or their counterparts) make up the so-called "higher-order thinking skills" (HOTS). Students are assumed to begin learning about anything (primarily specific conceptions) at the knowledge level, and then to evolve progressively, in a linear sequence, throughout the other five categories until they reach the mastery level of evaluation or creating.

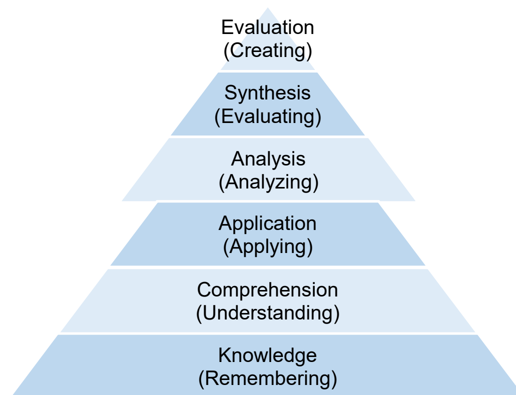

Figure 3. Original and revised (by Anderson et al., 2001) levelled categories of Bloom's cognitive taxonomy, with the top three categories making up HOTS.

The originally called "knowledge" and "comprehension" categories of Bloom's cognitive taxonomy pertain mostly to content knowledge that may be learned and recalled either by rote (knowledge or remembering) or meaningfully (comprehension or understanding). The subsequent four categories (application through evaluation, or applying through creating) pertain primarily to process knowledge. The former two categories are, in certain respects, the object of the epistemic dimension in our SCE taxonomy, and the latter four categories, but especially the original top three HOTS, make somewhat the object of our rational dimension (Table 1).

It is often assumed under Bloom's taxonomy, that students need to "comprehend" or "understand" a given conception (information of any nature, concepts or connections among concepts, etc.) *before* they can "apply" it in simple familiar contexts with low cognitive demands. It is also assumed that once they succeed applying the conception as such, students can move on to deploying it in "analysis" tasks, and subsequently in "synthesis" and "evaluation" tasks that supposedly impose increasingly higher cognitive demands. As such, Bloom's cognitive taxonomy is marred with many critical issues, among which we briefly discuss three issues here. The first relates to distinguishing "application" (and HOTS) from the two prior content knowledge categories. The second issue relates to the limitations of HOTS, and the third to the levelling of the six categories.

According to neuroscience, there is a difference in long-term memory (LTM) between *availability* and *accessibility*, i.e., between knowledge formation and sustainability in LTM, on the one hand, and knowledge retrieval from LTM on the other. The two are distinctive processes carried out by different neural networks in the brain, and require distinctive training from cognitive and pedagogical perspectives. Bloom's advocates would be on track had they attributed their knowledge and comprehension categories (or the revised alternatives) explicitly and solely to LTM availability, and application (and HOTS) to LTM accessibility. However, this is not the case for at least two reasons. First, these advocates do not tell us how to ascertain how knowledge "goes into" memory – and, actually, we do not have yet the pedagogical means to do so. Second, meaningful understanding of any conception cannot actually come about without deploying it in familiar (applying) and novel (HOTS) contexts. In fact, isn't that how we ascertain student "understanding" of content knowledge in assessments and various assignments, i.e., through "application" and deployment in tasks requiring analysis, synthesis, and evaluation (original HOTS), among others?!

HOTS do not cover all reasoning skills as we do in our SCE rational dimension. In that dimension, we distinguish five facets: analytical reasoning, criterial reasoning, relational reasoning, critical reasoning, and logical reasoning (Table 1). As the reader may notice from the outline of our facets in Table 1, and from the subsets identified elsewhere (Halloun, 2014), Bloom's analysis covers some but not all aspects (subsets) of our analytical reasoning facet, his synthesis is one subset among others of our relational reasoning facet, and his evaluation involves only one subset from each of our criterial and critical reasoning facets.

Under Bloom's taxonomy, a developmental hierarchy is assumed from the knowledge category up to the evaluation category. Notwithstanding the mix-up between epistemic and rational aspects discussed in the first point above, such hierarchy is not warranted, not even across so-called HOTS. As discussed in the previous section, and as far as we came to learn from neuroscience about cognitive development, there is no universal order in which various conceptions or reasoning skills are developed in our brain as we grow older in age and more knowledgeable with education. If anything, and as discussed in that section, each conception and each reasoning skill may gradually evolve through the five stages outlined in Table 2, beginning in early school years. Accordingly, the first three categories in Bloom's taxonomy and the new "creating" category at the top of HOTS may be associated with particular stages in this table. Bloom's knowledge category then comes close to our inception stage for conceptions as well as O/Ls, comprehension and application, to our emulation stage for conceptions as well, and creating, to our production stage for both conceptions and reasoning skills.

Select References

Anderson, L. W. (Ed.), R. Krathwohl, D. R. (Ed.), Airasian, P. W., Cruikshank, K. A., Mayer, R. E., Pintrich, P. R., Raths, J., & Wittrock, M. C. (2001). *A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives*. New York, NY: Longman.

Bloom, B. S. (Ed.). (1956). Taxonomy of Educational Objectives. The Classification of Educational Goals. New York, NY: McKay.

Bunge, M. (2000). Systemism: the alternative to individualism and holism. *The Journal of Socio-Economics*, 29, 147-157.

Bunge, M. (1983). *Understanding the World.* Dordrecht: Reidel.

Bunge, M. (1979). *A World of Systems.* Dordrecht: Reidel.

Halloun, I. (2020a). *Systemic Cognition and Education*. In preparation.

Halloun, I. (2020b). Model-based cross-disciplinarity within and with science in the framework of Systemic Cognition and Education. Submitted for publication.

Halloun, I. (2019a). *Systemism: A synopsis*. Working paper. Jounieh, Lebanon: H Institute.

Halloun, I. (2019b). Cognition and Education: A Bungean Systemic Perspective. In: M. Matthews (Ed.), *Mario Bunge: A Centenary Festschrift*, pp. 683-714. Cham, Switzerland: Springer.

Halloun, I. (2018a). *Systemic Convergence in Education*. Working paper. Jounieh, Lebanon: H Institute.

Halloun, I. (2018b). *Scientific Models and Modeling in the Framework of Systemic Cognition and Education*. Working paper. Jounieh, LB: H Institute.

Halloun, I. (2016). *Mind, Brain, and Education: A Systemic Perspective*. Working paper. Jounieh, LB: H Institute.

Halloun, I. (2014). *SCE Taxonomy of Learning Outcomes: Rational Subsets*. Jounieh, LB: H Institute.

Halloun, I. (2011). From modeling schemata to the profiling schema: Modeling across the curricula for Profile Shaping Education. In: Khine & Saleh (Eds), *Models and Modeling: Cognitive Tools for Scientific Inquiry*. (Models & Modeling in Science Education, Vol. 6, pp. 77–96). Boston, MA: Springer.

Halloun, I. (2007). Mediated modeling in science education. *Science & Education*, 16 (7), 653–697.

Halloun, I. (2004/6). *Modeling Theory in Science Education*. Dordrecht, Netherlands: Kluwer / Boston, MA: Springer.

Halloun, I. (2001). *Apprentissage par Modélisation : La Physique Intelligible*. Beyrouth, Liban : Phoenix Series / Librairie du Liban Publishers.

Appendix

SCE taxonomy and systemic programs of study

Our SCE taxonomy of learning outcomes is a generic taxonomy that applies to any field under any pedagogical framework. However, it gains full significance when deployed under systemic frameworks to define systemic competencies, and especially to spell out programs of study in the form of learning outcomes pertaining to well-chosen systems along pertinent dimensions of the system schema (Fig. 1).

Table 3 illustrates how our taxonomy, and specifically its epistemic and rational dimensions, may serve to spell out systemic programs of study, i.e., programs of study consisting not of isolated conceptions but of limited sets of powerful and lean (free of redundancies and superfluous information) systems that reflect patterns of interest in the physical world and/or the conceptual realm of academic knowledge. The table pertains to our planet Earth as a simple system delineated by convenience in terms of the function it is meant to serve (Box 1). The function considered for illustration is of describing, explaining, and predicting three particular terrestrial phenomena: the day and night cycle, seasons, and sea and ocean tides.

Such function requires us to take, to a very good approximation, a system environment consisting of only two agents, our Sun and Moon. It also requires us to work in a classic geo-astronomical framework that takes advantage of classical physics, namely: (a) Kepler's first and third laws specifying respectively the elliptical orbit of planets around the sun and the period of a complete revolution along such orbit; (b) Newton's universal law of gravitation; (c) Newton's second law of dynamics with a centripetal acceleration; (d) Euler's first law of rotational inertia; and (e) the approximation, from geometric optics, of sunlight hitting the Earth surface at a given time of a day as a beam of parallel light rays.

The following points are worth noting regarding Table 3:

1. Each row in the table provides, in adjacent separate cells, sample epistemic and rational learning outcomes (LOs) for a particular dimension of the system schema. The list of outcomes pertaining to any dimension of our taxonomy is there for illustration purposes only, and is neither exclusive nor exhaustive.
2. Epistemic and rational LOs in a given row do not necessarily complement or correspond to each other in a one-to-one match. A given rational LO may complement or correspond to more than one epistemic LO in the adjacent cell, and vice versa.
3. Each LO has a three-place label: The first letter denotes the taxonomy dimension (E for epistemic and R for rational), the following one or two digits give the LO order in the list of outcomes provided in either dimension, and the last letter denotes the corresponding facet in the taxonomy of Table 1 as indicated at the bottom of Table 3.
4. Schema dimensions and corresponding LOs are not listed in the order they need to be covered in a given course (they never are in such a table). This order depends on the nature of the object of learning (O/L), its place in the course, the learning ecology, and especially the actual competences (and competencies) of participating students.
5. Not all facets of a given dimension of our taxonomy (Table 1) are, or could necessarily be, covered with a particular O/L, whether it is an entire system or a part of a system.
6. Covered facets (and schema dimensions) do not necessarily have the same number of LOs. The nature and number of LOs depend on the O/L and its place in the course, and especially on the covered program of study.
7. As discussed in Section 4, a learning outcome needs to be stated so as to be clearly classified in one of the four dimensions of our taxonomy. To this end, the statement of every epistemic

learning outcome begins with “The student *realizes* that” in contrast to the statement of every rational outcome that begins with “The student *is able* to”.

8. Some statements in Table 3, and especially epistemic statements, are complex statements embodying more than one LO each. For precision purposes, especially in assessment, each of these statements need to be broken down into a number of distinct LO statements.
9. No “action verbs” are purposefully used in various LOs, especially not in rational outcomes. The same verb may be used with different conceptions or reasoning skills (e.g., to determine, to tell, to figure out). Similarly, different verbs may be used with the same conception or reasoning skill. However, certain verbs must be used exclusively with certain skills (e.g., to describe used only for description under the rational analysis facet, and to explain used only for explanation under the same facet as discussed in Section 5).

Table 3

The Earth system within a Sun-Moon environment in a systemic program of study

Schema \ Taxonomy		Epistemic Label*	Epistemic Sample Learning Outcomes	Rational Label*	Rational Sample Learning Outcomes
Framework			*The student realizes that*:		*The student is able to*:
		E1T	• The Earth system taken with the Sun and Moon as its sole agents (hereafter denoted by E/SM system) can be studied in a classical framework for the purposes set in the scope (E8).	R1L	• Figure out that the classical framework outlined in the introduction of the appendix (p. 20) suits the set purposes.
		E2T	• The classical framework is universal; it applies to any similar planetary system in the Universe.	R2L	• Figure out that there are universal maxims and premises that could be part of a variety of frameworks.
		E3T	• The framework involves maxims and premises shared with other frameworks that govern the microscopic world as well as the macroscopic and astronomical worlds (page 20).	R3K	• Refute with proper arguments the foundations of astrology.
		E4T	• E/SM is the object of scientific and non-scientific fields, including arts and literature.	R4K	• Ascertain certain foundations and claims in science fiction and outside science regarding the E/SM system.
Scope	Domain		*The student realizes that* the E/SM system:		*The student is able to*:
		E5E	• Is part of our Solar system that includes more planets and their satellite(s).	R5L	• Figure out that the defined system and framework are suitable for studying phenomena not only on Earth, but also on the Sun and the Moon as affected by Earth and each other.
		E6E	• Is a prototype of all planet/star & satellite(s) systems in the universe.	R6L	• Acknowledge convincingly that billions of systems similar to E/SM exist in the universe, all governed by the same laws as the E/SM system.
		E7E	• Represents all celestial objects that are centrally bound by the gravitational interaction.	R7C	• Specify the criteria according to which the E/SM system can serve as a model or prototype for other planetary systems.
	Function		*The student realizes that* the E/SM system serves:		*The student is able to*:
		E8C (PD & PE)	• To describe, explain, and predict many phenomena on Earth including the occurrence of: • day and night; • seasons; • tides.	R8K	• Figure out that, though related, the three functions, and especially description and explanation are distinct functions that need to be addressed distinctively.
		E9T	• For the development, in certain respects, of scientific theory and paradigm.	R9K	• Determine which questions the E/SM system/model can answer and which it does not.
		E10T	• To inspire various artistic and literary works, real or fictional, and even some mythical and anti-scientific beliefs.	R10L	• Acknowledge convincingly that, should planets similar to Earth exist in the universe, the three phenomena and their impact on possible life would occur similarly on those planets.

Schema \ Taxonomy		Epistemic		Rational	
		Label*	**Sample Learning Outcomes**	**Label***	**Sample Learning Outcomes**
Constitution	Composition		*The student realizes that*:		*The student is able to*:
		E11D	• For the purpose of studying the three phenomena of interest (E8), Earth can be considered, to a very good approximation, as a "simple" spherical object with no particular composition to take into consideration (The same goes for the other two celestial bodies, Moon and Sun, in the Environment).	R11A	• List the features (entities and their properties) of the E/SM system and distinguish between primary and secondary features for any particular function of the system.
				R12K	• Figure out that considered primary features are specified with a certain level of approximation that is suitable for the distinguished purposes (e.g., assuming that the three celestial objects are spherical).
		E12D	• The primary Earth properties that need to be considered for the study of the three phenomena in question include its mass (only if gravitational forces need to be evaluated), its spherical shape, its axis of rotation, and its position at specific times relative to the Moon and Sun.	R13R	• Recognize the need for an appropriate reference system in which to situate the E/SM system.
				R14R	• Figure out which properties depend on the choice of the reference system and which do not.
	Structure		*The student realizes that*:		*The student is able to*:
		E13C (MD)	• The internal structure of Earth (like that of the other two celestial bodies) can be ignored for the purpose of studying the three E8 phenomena.	R15A	• Figure out that natural interactions in the Earth biosphere have no significant impact on the three phenomena of interest and can thus be ignored.
		E14D & C (MD)	• In 2018, the Earth's axis of rotation is tilted at an angle of about 23º 26' with respect to the normal to the plane of its elliptical orbit around the Sun.	R16K	• Figure out that human activities on Earth may have a significant detrimental impact on the three phenomena of interest, though to different degrees, and should thus be constructively controlled.
		E15C (PD)	• The tilt angle of the Earth's axis of rotation constantly changes, though slightly, throughout the years.	R17 C & L	• Figure out that eventually, and after thousands of years, Earth's axis of rotation will get reversed (thus reversing seasons in the two hemispheres).
	Environment		*The student realizes that*:		*The student is able to*:
		E16E	• The primary agents of Earth that need to be considered are: the Sun for the first two E8 phenomena (day and night, seasons), and the Moon for the tides.	R18A	• Determine why external agents (Sun and Moon) and not the Earth itself are behind the three phenomena of interest (E8).
		E17D	• Aside from their position relative to Earth, and only if gravitational forces need to be evaluated, the mass of each agent is the only intrinsic primary property to take into consideration.	R19A	• Determine why the Earth position relative to the two agents and the relative masses of the latter celestial bodies are primary determining factors in the three phenomena.

Schema \ Taxonomy		Epistemic Label*	Epistemic Sample Learning Outcomes	Rational Label*	Rational Sample Learning Outcomes
Constitution	Ecology		*The student realizes that*:		*The student is able to*:
		E18C (PE)	• For the functions considered in E8, we only need to consider the actions on Earth of its agents, the Sun and the Moon, and not the reciprocal action of Earth on its agents.	R20C	• Figure out that neighboring planets interact with Earth but have no significant effect on the E8 phenomena..
		E19C (PE)	• Kepler's Laws and Newton's laws of mechanics govern the motion of all three celestial objects.	R21L	• Infer similarities and differences between the E/SM system and the Bohr model of the atom.
		E20C (ME)	• The change of position, from day to night and from one day to another, of a given spot on Earth relative to the Sun and the Moon causes a change in the net gravitational interaction at this spot with the two agents.	R22L	• Deduce the universality of interaction laws in content (e.g., dependence on mass/charge and distance in gravitational/ electrostatic laws) and form (e.g., the inverse square).
Performance	Processes		*The student realizes that*:		*The student is able to*:
		E21C (PD)	• The primary processes that need to be considered for the study of the three phenomena of interest (E8) pertain respectively to the Earth's rotation around its axis (day and night), its elliptical orbit around the sun, with attention to its inclined axis of rotation (seasons), and the Moon's elliptical orbit around the Earth (tides).	R23A	• Describe how the angle of incidence of sunlight varies from one spot to another on Earth at a given time, and from day to day at the same spot.
				R24L	• Get convinced that Earth revolves around the Sun and not the other way around.
		E22C (PD & PE)	• Earth rotates around itself (around its virtual axis of rotation) once every almost 24 hours, and its rotational motion is governed by Euler's laws.	R25A	• Describe how the relative duration of day and night varies with seasons.
				R26R	• Relate the occurrence of equinoxes to the position of the Earth relative to the Sun.
		E23C (PD &PE)	• Earth moves in an elliptical orbit around the Sun once every almost 365 days, and its translational motion is governed by Newton's laws of the centrally bound particle model.	R27A	• Relate the change of apparent positions of sunrise and sunset to the orbit of Earth around the Sun.
				R28A & L	• Acknowledge that there are different seasons at the same time in different countries around the globe, and particularly opposite seasons in the two hemispheres.
		E24C (PD)	• The Moon orbits around Earth in an ellipse, with the Earth at one of the foci, just like the Earth does around the Sun.	R29L	• Figure out why the tilt of the Earth's axis of rotation and not its relative position to the sun is the determining factor for the occurrence of seasons.
				R30A	• Explain why sea and ocean water moves inland and outland during tides.
				R31C	• Explain why tides are more pronounced in oceans than in seas.

Taxonomy / Schema		Epistemic		Rational	
		Label*	**Sample Learning Outcomes**	**Label***	**Sample Learning Outcomes**
Performance	Output (extrapolated beyond the original scope)		*The student realizes that*:		*The student is able to*:
		E25C (PE)	• The day-night cycle results from Earth rotation around its axis in front of the Sun.	R32R	• Set longitudes and latitudes, and specify how longitudes determine time zones and latitudes, climate and seasons.
		E26C (PE)	• The quasi-spherical shape of the Earth and the tilt of its axis of rotation cause: (a) sunlight to hit different regions of Earth at different angles of incidence in a given time, and (b) change, from day to day, of that angle of incidence at a particular spot on Earth as it orbits around the Sun.	R33A & L	• Explain each phenomenon in terms of the appropriate causal law.
		E27C (PE)	• The change of seasons in a given country results from the change, from day to day, of the angle of incidence of sunlight and not of the position of Earth relative to the Sun (Fig. 4).	R34A	• Figure out why the tilt of the Earth's axis of rotation and not its relative position to the sun is the determining factor for the occurrence of seasons (Fig. 4).
		E28C (PE)	• The differential gravitational attraction by the Moon on different points on Earth (which is more significant than that of the Sun) results in sea and ocean tides.	R35C	• Compare the effect of the Sun and the Moon on tides in terms of the magnitude of the gravitational forces they exchange with the Earth.
		E29C (ME & PE)	• Earth elliptical revolution around the Sun (just like Moon around Earth) brings about many effects in addition to seasons and weather and climate changes. These include a variation of the gravitational interaction between the two celestial bodies that goes from a minimum when Earth is farthest away from the Sun to a maximum when it is closest to it, which in turn results in the Earth moving slowest on its orbit in the former case and fastest in the latter.	R36R	• Compare the impact on heat, and thus on climate and seasons, due to the variation, in space and time, in the angle of incidence of sunlight on earth.
		E30C (PD & PE)	• Earth rotation around its inclined axis of rotation brings about, in addition to the day-night cycle, numerous effects including its precession (wobbling like a top) with a period of around 26,000 years (for a complete turn).	R37R	• Compare the impact on heat, and thus on climate and seasons, due to the change of the distance between the Earth and the Sun at different times of the year.
		E31C (PE)	• The Moon's revolution around Earth brings about, in addition to the tides, numerous effects like the apparent phases of the Moon.	R38A	• Explain and predict the phases of the Moon in a lunar cycle.
		E32C (ME & PE)	• The three phenomena herein considered have particular impacts on life on Earth.	R39C	• Specify how the Moon phases can be determined in a particular time of the lunar cycle (how to tell from the shape of the Moon).
				R40A	• Relate the occurrence of eclipses to the relative position of the Sun, Earth and Moon.
				R41K	• Formulate proper questions about the origin and evolution of the E/SM system.
				R42K	• Formulate hypotheses about the relative impact of the three phenomena herein covered on life on Earth, and their socio-economic impact.
				R43L	• Generalize the three phenomena and their impact on life to other planets in the universe, should there be planets similar to Earth.

* The last letter in the label of an epistemic learning outcome corresponds to the appropriate facet and more in Table 1 as follows: “T” for a theory or set of theories in a given paradigm, “E” for situated entities’ object concepts, “D” for descriptors or property concepts, and “C” for conceptual connections. For further distinction and relation to other facets, “C” is followed in parentheses with: “MD” for descriptive morphology, “ME” for explanatory morphology, “PD” for descriptive phenomenology, and/or “PE” for explanatory phenomenology. MD and ME are respectively about the description and explanation of constitution in the system schema (Fig. 1), and PD and PE, about the description and explanation of performance. The depictors facet is partially illustrated in Figure 4, whereas the operators facet is omitted in this table. The latter is primarily about all laws that have been listed and not formerly stated or expressed in this table for simplicity.

* The last letter in the label of a rational learning outcome corresponds to the appropriate facet in Table 1 as follows: “A” for analytical reasoning, “C” for criterial reasoning, “R” for relational reasoning, “K” for critical reasoning, and “L” for logical reasoning.

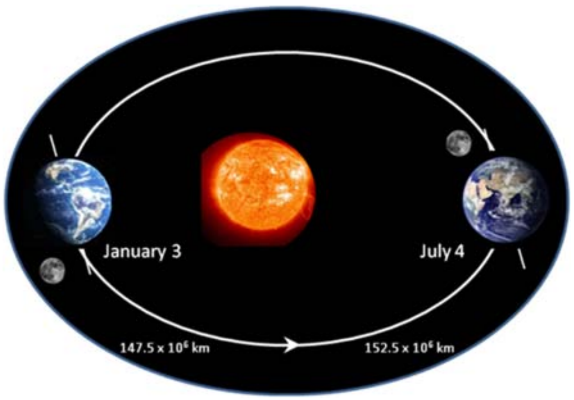

Figure 4. Graphic depiction of the Earth / Sun-Moon system (E/SM).

The three celestial bodies are loosely depicted to show their relative positions on two specific days of the year when Earth is closest to (3 January) and farthest away (4 July) from the Sun, and when, contrary to common sense, the northern hemisphere is in its winter and summer seasons respectively. Note how the tilted axis of Earth rotation makes sunlight hit the northern hemisphere almost vertically on July 4 but not on January 3 (with the opposite true for the southern hemisphere).