Curriculum design in the framework of Systemic Cognition and Education (SCE): An introduction

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This is a working paper written for a specific cohort of students to guide their work in a graduate course about curriculum design and deployment.

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Halloun, I. (2018/19). ***Curriculum design in the framework of Systemic Cognition and Education (SCE): An Introduction*****. Working paper. Beirut, LB: Lebanese University.**

No formal education comes about without appropriate curricula. Nonetheless, educationists (education theoreticians, including policymakers) and educators (practitioners like teachers, supervisors and school principals) often disagree amongst themselves and between each other as to what a curriculum is and what it entails. On one end of the spectrum stand some educators who mix up a curriculum with a program of study and restrict it to the content of a set of courses pertaining to a specific academic field or subject-matter. On the other end of the spectrum stand some other educators, along with many educationists, who consider that a curriculum is far more involved. For the latter people, a curriculum includes, in addition to one or more programs of study, detailed prescriptions for means and methods of learning, instruction, student assessment and curriculum evaluation, all designed to achieve specific purposes under a given local or global philosophy and deployed under a well-defined pedagogy.

Purpose, or what a curriculum is for, is perhaps the most distinguishing aspect among various forms of curricula. For some (educators and educationists), a curriculum is "academia-focused" or "discipline-oriented". It is for the "delivery" of certain "academic knowledge" or subject-matter. For others, any curriculum should be "learner-focused" or "traits-oriented". It is for the cognitive and physical "development" of humans of certain age and affiliation or identity, and thus for bringing about graduates with specific traits. Thus, while academic knowledge is an end by itself in academia-focused curricula, it is means to an end in learner-focused curricula, the end being then the learner overall profile or specific traits of it.

Desired traits in learner-focused curricula could be dogmatic and uniform, like in the case of totalitarian regimes and some monarchies that condition submissive followers, or liberal and generic, like in the case of true democracies that leave it to local communities or schools to decide what is best for their constituency. Discipline-oriented and dogmatic traits-oriented curricula are usually one-size fits all curricula. A curriculum of the sort is a rigid entity that all concerned stakeholders should adopt alike, and thus interpret and implement exactly the same way. This is also the case of centralized educational systems, like the Lebanese educational system, that claim to be in neither of the latter two categories!

Learner-focused policy and decision makers are nowadays constantly calling for educational curricula and institutions to bring about graduates with profiles (comprehensive sets of traits) suitable for the 21st century. Our lifestyles are evolving at an unprecedented pace, with the fast changes increasingly taking place at home, school, work, and anywhere around us. Many existing professions are being continuously redefined, and new professions are increasingly emerging in the job market, often with unprecedented and even unforeseen requirements (Brennan et al., 2014; OECD, 2013; others). A curriculum should thus be for *empowering students with dynamic profiles* that continuously evolve to meet the challenges of modern life, profiles that are good *not merely for passing school and other exams, but for lifelong learning and continuous success outside the school boundaries in various aspects of everyday life*.

This requires a new perspective on curricula, even a major paradigm shift in education, especially in general education, that may ultimately require to reconsider the role and structure that schools have traditionally assumed, and eventually consider new concepts of educational system and schooling that drop the 2-4-6 model altogether. This model assumes that knowledge (academic knowledge) is confined between the 2 covers of a textbook, and can be "delivered" between the 4 walls of a classroom typically during 6 periods a day.

For the stated purpose, we adopt a generic learner not academia focused approach for curriculum design and deployment (i.e., implementation in any possible form and way within and beyond the scope of the curriculum) that stakeholders in any area and at any level of general and vocational education can tailor to their needs. Our approach is underlined primarily by the premise that, in order to optimize the viability and efficiency of various curricular products and processes, any curriculum must be put together, and allowed to evolve, in harmony with all mental and physical entities within and around us. Such entities, which include our body and mind, the family, the workplace and all sorts of social and natural organisms we interact with, consist, like all entities in the universe, of *dynamic systems* that constantly interact with each other and evolve in order to achieve specific purposes (with pre-determination or not!). Accordingly, a curriculum is for us a *dynamic system* designed and deployed for the purpose for bringing about graduates with *systemic profiles* for success in life, at the personal and collective levels.

This working paper comes in four sections and an appendix. It begins with an outline of learner-focused curricula that bring about students with systemic profiles of particular 4P traits. It follows with a section on systemism, a generic worldview according to which everything in this world, whether natural or human-made, physical or conceptual, is best conceived as a system or part of a system that can be defined in accordance with a four-dimensional systemic schema presented in the same section. Systemic Cognition and Education (SCE), a generic pedagogical framework developed by this author for teacher and student education of all types and levels, is quickly introduced in the third section to be detailed later in the appendix. An outline, under SCE, is provided in the same section of systemic curricula in accordance with the aforementioned systemic schema and of related taxonomy of learning outcomes for systemic design and deployment of various learning, instruction, and assessment tools. The section ends with critical threshold that students go through as they gradually develop profiles and learning outcomes. The fourth section provides major provisions for sustainable learning and meaningful development of systemic 4P profiles under SCE, major tenets, principles, and rules of which follow in the Appendix.

1. Learner-focused curricula for systemic profiles development

A curriculum is always designed to serve certain purposes for a group of students, individually and/or collectively. In general education, these purposes have traditionally been limited to, and constrained by, specific aspects of a particular discipline or a particular field of study comprising a number of disciplines. In vocational education, curricula have usually been designed to drill students on following particular routines for completing specific tasks in the workplace.

1.1. Types of curricula

Different curriculum types may be distinguished depending on categorization criteria. We have already distinguished above two types of curricula based on the ends curricula serve. We can further classify all curricula, as we have just started above, in two other broad categories depending on the extent to which they take into consideration students' aspirations and needs and leave room for learning experiences outside the confines of a given curriculum. The first category consists of closed and rigid curricula, like discipline-oriented and dogma- or dogmatic traits-oriented, which ignore students’ aspirations and prospective needs in their society. The second category consists of open and flexible curricula which make way for students and teachers to cross the boundaries of any curriculum structured around a given field or subject-matter into other fields and various aspects of everyday life. Closed curricula usually culminate in a certificate or diploma based on a limited set of high-stakes exit exams. Open curricula may also culminate in a diploma, but this diploma is usually based on a student’s cumulative performance throughout the study period and not just one set of exit exams.

Dogma-oriented curricula are meant to prepare students to serve certain political or cultural strategy, and condition them to behave in specific ways in the workplace and daily life. Discipline-oriented curricula are designed in general education to help students develop mostly content knowledge pertaining to specific fields of study independently of the students' aspirations and the community needs. The same goes in vocational or technical curricula whereby students develop specific technical content and process knowledge (often referred to as competencies) pertaining to a current or prospective job, a community engagement or hobby, which, unlike their peers in general education, they might have chosen at their free will.

Open curricula accommodate individual students' needs, and may somewhat take into consideration the community and/or nation needs. Some open curricula allow individual students to opt for the field(s) of study of their choice, and sometimes to pursue their study at their own pace. Others set a graduate profile with a mix of mandatory and optional traits. Mandatory traits normally depend on the community / nation needs and are required of all students, and optional traits are left to individual students to choose and develop.

The use of the term "subject" or "subject-matter" instead of "discipline" associated with any curriculum and any given course reflects, at least in part, the pitfalls of traditional curricula and conventional instruction that are mostly academia-focused. Terms like subject and subject-matter (or matter for short in some languages, e.g., "matière" in French) refer more to content than processes, and more to static, stagnant, and inert than dynamic, evolving, and living states. Such terms also imbed some form of closeness, impermeability and isolation, or at least some form of compartmentalization, within and across various "subjects", which most of our students end up with when storing course materials –mostly content knowledge– in their memory (more in the short-term than the long-term). Processes of knowledge construction, organization, retrieval and deployment associated with, and often common to various disciplines do not get the attention they deserve in the classroom and course materials, and students are then often left to wander in dark labyrinths inside and outside the classroom. Most critically, students are driven to lose interest in formal education, and, as research has often shown, to find refuge in digital devices, outside the classroom, and "passionately" seek the information and develop the processes they think are pertinent to everyday life and the prospective profession they are after.

We live in a time when societies are increasingly opening up and interacting with each other, and requirements for success in life and the workplace are constantly changing in many respects. For individuals to be ready to accommodate such changes, they should be motivated enough to do so, and empowered for continuously seeking on their own means to develop their knowledge, i.e., empowered for lifelong learning. In short, we need nowadays, more than ever before dynamic educational systems that work with open and dynamic learner-focused curricula.

1.2. Learner-focused curricula

Learner-focused curricula are meant to bring about graduates with profiles of particular traits that meet the needs and aspirations of those graduates and the community they belong to. They do so under particular pedagogical frameworks (theoretical entities) and in the context of appropriate learning ecologies (practical entities) that are convenient for curriculum deployment, and thus graduate profile development (Fig. 1).

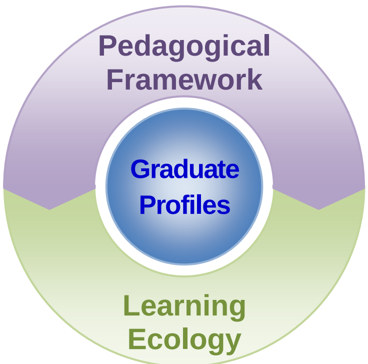

Figure 1. Learner-focused curriculum.

A pedagogical framework governs all aspects of curriculum design and deployment and stems primarily from broad cognitive and educational premises while respecting the same cultural and geo-political choices of the community that led to the definition of the desired graduates' profiles.

A learning ecology consists of: (a) all actors (students, teachers and other learning/ instruction agents), and (b) physical and operational settings, along with (c) appropriate schemes to bring actors and settings together, and manage and continuously enhance settings and operations, especially the interaction between individual students and various actors and settings, in order to bring about the graduate profiles under the chosen pedagogical framework. Traditionally, schemes in question pertain primarily to learning, instruction, and assessment.

The most meaningful profile development at all schooling levels occurs through experiential learning, i.e., through "transaction" – a term we borrow from John Dewey (Archambault, 1964) and Mario Bunge (1967a) – with real entities (objects and events included) in an appropriate learning ecology. *Experiential learning* is about a learner's conscious and purposeful experience with one or more real world entities in a favorable learning ecology that includes, in addition to these entities (referred to hereafter as "objects of learning"), other elements that contribute to the course and outcome of the experience. In particular, experiential learning involves:

- *A learner*, i.e., an individual student in formal education, who is engaged in the learning experience to fulfill specific purposes. In formal education, these purposes are typically set in a given curriculum in some form of content and process knowledge that students are expected to develop about, and in the context of, particular objects of learning.
- *Objects of learning*, i.e., various physical and/or conceptual entities about which, and in the context of which, the learner is expected to develop the expected knowledge (e.g., the human body or parts of it, a poem, a particular scientific concept or model).
- *Learning agents*, i.e., peers, teachers, parents, and other people with whom the student may significantly interact during the learning experience, inside and/or outside school.
- *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).

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

- The purpose(s) set for the learning experience.
- The sensory-motor and cognitive (mental and affective) state of the learner.
- The state of the objects of learning and of all other elements in the learning ecology distinguished above.
- Transaction efficiency, i.e., the efficiency of all rational, affective, and sensory-motor exchanges that take place between the learner and all elements in the learning ecology.

1.3. Systemic 4P profiles

Research in cognitive psychology reveals that accomplished professionals are distinguished from other people more in the ways they organize and deploy their knowledge than in the "amount" of knowledge they possess. These "experts" often adopt, consciously or unconsciously, a *systemic worldview* whereby they conceive everything around us as systems or parts of systems, and systematically follow systemic ways of constructing, organizing, and deploying their knowledge. Formal education should thus be systemic in the sense of bringing about learners with systemic profiles that embody professionals' patterns of success in modern life and that have at least four major general traits in common that would qualify them as 4P profiles.

A *4P profile* is the dynamic, constantly evolving profile of a systemic, well-rounded citizen empowered for lifelong learning and success in life, and characterized with progressive mind, productive habits, profound knowledge, and principled conduct (Fig. 2).

Figure 2. 4P profile.

The four P's are not absolute traits of a "one-size fits all" profile. They are universal "qualifiers" for distinct individual profiles which reliable research in cognitive science has constantly proven to be necessary for success – and excellence – in any aspect of life, at the personal and collective levels, and in any era, especially our modern era (Halloun, 2017 a & b).

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

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

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

- ❖ Ask appropriate questions about any situation, devise flexible plans to deal with it, ascertain plans efficiency before carrying them out, systematically carry out those plans, evaluate them and refine them in the process.
- ❖ Identify or put together systems (in accordance with the schema of Figure 3) to deal efficiently with physical or conceptual situations and identify structural and behavioral patterns within and across situations.
- ❖ Ascertain their own knowledge, consolidate their strengths, regulate their weaknesses, and resolve incoherence and inconsistency among their own ideas.
- ❖ Develop sound criteria and processes for selecting, using, and sharing appropriate resources, communicating ideas and cooperating with others,

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

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

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

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

2. Systemism and systemic schema

Our knowledge of and about the world is the result of transaction between physical realities (humans included), as they exist in the real world independently of how we might perceive them, and the rational realm of our human mind. Such transactions are best conceived and carried out when both the real world of physical entities, humans and their brains included, and the rational realm of our mind are conceived as systems, or parts of systems, of well-defined structural and functional characteristics. A systemic worldview (systemism) allows us to enhance the efficiency of our transaction with concrete objects and to bring cohesion and coherence to our knowledge of and about the world.

Systemism allows us to bring cohesion and coherence to this world, as well as to our own thinking, to better make sense of this world, and to understand certain aspects of this world that may not be easily conceived – and perhaps that may not be conceived at all – without such perspective. Under systemism, everything in this world, whether natural or human-made, physical or conceptual, is a system or part of a system. Systems infuse order in the world, and help us reveal patterns in the universe, from the astronomical scale down to the subatomic scale, as well as in human body and mind. Systemic processes help us, as best as possible, systematize knowledge construction, organization, retention, and deployment, and take full advantage of brain and mind patterns in any mental or sensory-motor process or product (Halloun, 2019).

A system has been defined in a variety of ways in the literature, but they all converge on that a system may consist of one entity (if simple) or many interacting or connected entities (if compound) confined within well-defined boundaries to serve particular purposes. The constituent entities, and thus the system, may be either physical, if consisting of material objects, or conceptual, if consisting of abstract elements (e.g., scientific models).

Figure 3. Systemic schema.

We define a system of any sort, in both the physical world and the conceptual realm of human knowledge, in accordance with a four-dimensional schema (Fig. 3) that specifies the system's scope, constitution, and performance in the context of an appropriate framework (Halloun, 2011, 2017a & b).

1. The *framework* of a system consists of all: (a) theoretical premises, like assumptions, principles, value system, and other ontological, epistemological, methodological, and axiological maxims and provisions typically spelled out in the paradigm of a professional community, and (b) ensuing strategic choices, which, along with theoretical premises, guide the specification and reification of the following three practical dimensions of a system.
2. The *scope* of the system specifies:
   a. the system *domain*, or the field or area in which it exists and is of importance;
   b. the system *function*, or the specific purposes it is meant to serve in that domain.
3. The *constitution* of the system specifies:
   a. the system *composition*, i.e., its primary constituents which may be physical or conceptual entities (objects and their primary individual properties) inside the system that are relevant to its function, as opposed to secondary entities that may be part of the system but that may be ignored because we deem them irrelevant to the system function;
   b. the system *structure*, i.e., primary connections (interactions or relationships) among primary constituents that significantly affect 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, 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).
4. The *performance* of the system specifies:
   a. the system *processes*, i.e., dynamical actions (mechanisms or events) 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.

3. Systemic curricula under SCE

Education is, and must be explicitly carried out as, a systemic process that involves the interaction among many complex systems at the core of which is the most important system of them all: the individual learner. All other systems are there to facilitate the continuous development and empowerment of the learner for lifelong learning, and for a decent and successful life. For education to be really systemic, it has to be so in all respects. It has to explicitly and systematically target students as learning systems under systemic curricula.

Systemic curricula are learner not academia focused curricula designed under systemic pedagogical frameworks to empower students with systemic 4P profiles. They mandate to this end systemic programs of study, and provide for meaningful and insightful coverage of these programs in dynamic learning ecologies that rely on experiential learning and systemic assessment. Systemic curricula do not come in one-size fits all. They are flexible enough to account for cognitive and behavioral differences among learners of the same age group, and cater for the same learner to the distinctive cognitive needs imposed by different dedicated cerebral parts where learning outcomes of different types are encoded (Halloun, 2017a and 2019).

3.1. Systemic Cognition and Education (SCE)

Like any system, we define a systemic curriculum in accordance with our systemic schema (Fig. 3) under the framework of Systemic Cognition and Education (SCE). SCE is a generic pedagogical framework that we are developing for teacher and student education of all types and levels. The framework is outlined in the Appendix. It emerges from our work on modeling theory in science education (Halloun. 2001, 2004/6, 2007, 2011) and from a number of reliable sources, including but not limited to the following:

1. Research in educational psychology, cognitive science, and neuroscience, especially the neuro-educational field known as Mind, Brain, and Education (MBE). In particular, SCE: (a) draws on reliable findings on how our students actually are and think at specific school ages, what they can accomplish at a given age, and how they can realistically evolve throughout the years, and (b) avoids educational myths, fantasies, and any uncorroborated beliefs and perspectives still held in the educational community.
2. Comparative research among experts in different professions, and between them and novices (especially students), with particular attention to expert patterns of knowledge construction, organization, and deployment, and profile traits required for lifelong learning and success in modern life.
3. Seminal works on: (a) prominent educational theories, like information processing theory, conceptual change, and Piaget and Dewey's constructivism, (b) metacognition and various types of dispositions or worldviews that affect learning, and (c) prevalent pedagogical frameworks, like standards-based education (including standards for the use

of ICT in education), competencies-based and outcomes-based education, and European qualifications, to list a few.

4. Philosophy and history of science and other academic fields.

Some broad tenets of SCE:

1. The universe is best conceived as sets of interacting systems, and so do human beings, whether individually or collectively.
2. Systems are best conceived in middle-out structures between big pictures (patterns, in particular) and elementary details, and when they are systematically put together in accordance with a four-dimensional schema for specifying system framework, scope, constitution, and performance (cf. Halloun, 2019, §1, and Halloun 2017b, §2).
3. The human brain is physically and cognitively predisposed for continuous development and thus for lifelong learning and continuous content and process knowledge development.
4. Learners are dynamic systems for knowledge construction and deployment. They learn most meaningfully and productively in experiential learning ecologies (cf. Halloun, 2019, §1 and §2, and Halloun, 2017a, §3).
5. Sustainable learning. i.e., learning that lasts in long term memory, is primarily determined by the quality of the "conceptual image" formed of any object of learning through reiterative processes that take place in various parts of the brain. Processes include encoding, consolidation, storage, and retrieval of information under certain metacognitive controls that focus attention on lean systemic aspects of objects of learning and keep regulating the conceptual image insightfully until it brings any learning experience to its desired ends with the least cognitive load and the highest cognitive efficiency possible. (cf. Halloun, 2019, §2, and Halloun, 2017a, §4).
6. Formal education is not for the delivery of academic content and process knowledge but most importantly for student empowerment for efficient lifelong learning, construction – not assimilation – and creative deployment – not routine application – of meaningful and productive knowledge.
7. Systemic curricula are optimized when conceived and deployed with a focus on cross-disciplinarity (XDP). XDP is about building bridges among different disciplines to serve practical, systemic purposes while recognizing that no "discipline or scholarly field is an island unto itself; it is created, evolves, takes shape and responds in certain cultural, social and intellectual circumstances" (Matthews, 2012). Under systemic education, XDP is achieved when at least some systems in a given program of study are constructed with constituents coming from traditionally different disciplines, and when these systems are deployable in a variety of such disciplines, so as to bring coherence and consistency within and among disciplines, and facilitate transfer across disciplines and to everyday life.

3.2. Systemic curricula

A systemic curriculum is systemic both inherently and in the ways it helps students develop their profiles. It takes the form of a dynamic, flexible system; it works within the context of a field of study defined (or re-defined) around systems of cross-disciplinary nature; and it helps students systematically develop systemic habits for knowledge construction and deployment, and thus for profile development in the context of designated cross-disciplinary systems.

Under SCE, a curriculum is a dynamic pedagogical system for empowering students with 4P profiles for lifelong learning and success in modern life, at the personal and collective levels. It is designed primarily not to deliver academic knowledge but to serve students' needs for personal development, self-fulfillment, and high-standard achievements at school and beyond. These include immediate needs for cognitive, metacognitive, and physical development, and prospective needs for higher education, career preparation, and lifelong learning, as well as for induction in the workplace and continuous professional development. They also include needs for positive and effective engagement with others, the community with its cultural heritage, and the workplace with its ethical norms and standards. Like any system, we define a systemic curriculum in accordance with our systemic schema (Fig. 3) as follows:

Pedagogical framework:

A pedagogical framework is a conceptual system that consists primarily of theoretical and practical premises that govern the actions of all curriculum stakeholders, especially those who design and oversee the use of various curriculum materials. Premises may either lay the cognitive or pedagogical foundations of a curriculum or stipulate and prescribe the fundamental operations needed to deploy it in accordance with these foundations. Accordingly, we distinguish two types of foundational premises, tenets and principles, and one type of operational premises, rules. These premises are defined in the Appendix where corresponding SCE statements are presented.

Scope:

A learner-focused curriculum is designed for a community of students of specific age group and characteristics. It serves to empower these students with profiles that meet their individual needs and aspirations in relation to the community they belong to. Students gradually develop the target profiles during a specific period of time, partly or entirely at certain schools within a particular educational system.

A curriculum may be designed around a specific field of study that may pertain to one particular conventional discipline (e.g., language(s), mathematics, science, social studies, in general education) or a blend of disciplines.

SCE favors systemic curricula designed to bring about students with systemic 4P profiles in cross-disciplinary contexts.

Constitution:

A curriculum has traditionally been mandated and maintained through a combination of some or all of the following five facets: program of study, learning schemes (means and methods), teaching schemes, assessment schemes, and evaluation schemes (Fig. 4). The program of study sets the scope and sequence of content and process knowledge that students are expected to develop about, and in the context of, a given field of study. Textbook authors and developers of other resources come up then with course materials meant to help students develop what the program of study entails. Students resort to specific learning schemes

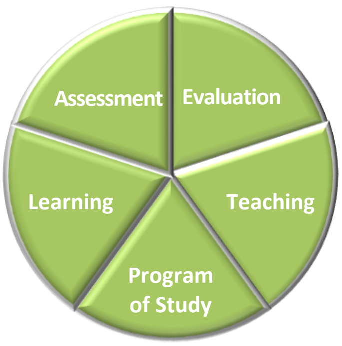

Figure 4. Traditional curriculum constitution.

to learn (mostly to assimilate in traditional sense) what these materials deliver about the program of study following teachers' instructions. At certain points of instruction, teachers (and/or other authorities) resort to certain assessment schemes in order to ascertain to what extent students have achieved delivered knowledge. The outcome is sometimes invested in evaluating specific aspects of the curriculum, and curriculum refinement or reform may subsequently be called for.

Under traditional educational systems, facets of interest are not necessarily coherently designed and deployed, and do not come necessarily aligned with a pedagogical framework supposedly behind the concerned curriculum. Traditional curricula are mostly academia-focused and follow the 2-4-6 model for the delivery of certain academic knowledge. As such, the program of study is supposed to help deployment agents, from developers of course materials to teachers and other immediately concerned (proximal) learning agents, conveniently design and implement other applicable facets of Figure 4. However, this has often not been the case, especially when high-stakes exit exams are in place like in the case of Lebanese curricula. Traditional curricula have often been exam-driven, with assessment as an end by itself and not as means to an end. They have been geared in practice toward preparing students to blindly pass exit exams at the detriment of meaningful learning of course materials. They often compel students to retain in short term memory certain content knowledge and routines for answering questions and solving problems typically asked in such exams rather than help students sustain in long term memory meaningful learning of what the program of study entails.

Under SCE, a curriculum is a dynamic, flexible system that does not follow the 2-4-6 schooling model for the delivery of programs of study, but that promotes the development of 4P profiles in suitable learning ecologies. As such, a systemic curriculum is designed under SCE in accordance with the systemic schema of Figure 3, and is more specifically constituted as follows.

Composition: A systemic curriculum comprises a systemic program of study consisting of cross-disciplinary systems that provide the proper context for developing 4P profiles. Any object of learning, whether physical or conceptual, is conceived in the program of study as one of these systems or as a primary constituent of such systems.

Structure: Various objects of learning, whether systems or parts of systems, are chosen in function of student needs and potentials, especially from a cognitive perspective (cf. §4 below), and structured in accordance with SCE taxonomy of learning outcomes to make the object of, or provide the context for, specific and generic competencies that lead to the formation of 4P profiles (Halloun, 2017b). Competencies and system development takes place gradually in a given school year, and across many years, in a helicoïdal approach that respects natural brain and memory development (cf. §2.4 in Halloun, 2019), and cognitive development stages (cf. §2.4 in Halloun, 2019) that lead gradually to the mastery of individual systems (cf. §3.4 below).

Environment: Various learning, instruction, assessment, and evaluation means are properly and coherently conceived to facilitate experiential learning with various objects of learning in proper settings (resources and ambiance). Assessment is conceived not as an end by itself, but far more "as" and "for" learning than "of" learning, i.e., far more as means of learning (first and foremost) and for guiding learning and instruction than for simply ascertaining student achievement (cf. Principle 17 in the Appendix).

Ecology: Teachers and other learning agents set resources and ambiance in accordance with SCE tenets and principles (Appendix) and make necessary provisions (§4) to ensure systemic learning ecologies (cf. §3.3 in Halloun, 2019) that would induce productive and meaningful experiential transactions of individual students with various objects of learning, with each other, and with learning agents.

Performance:

Under conventional instruction of lecture and demonstration, students are treated as fervent followers of what the program of study dictates and obedient spectators of their teachers' performance in class, and are expected to passively (and often blindly) assimilate delivered messages. Conventional processes are thus knowledge delivery processes. Corresponding output is restricted to the assimilation of specific content knowledge and routines required for passing school and exit exams. Processes are carried out primarily by teachers whose profiles are typically mandated by the expected output (academic knowledge) and the necessary delivery mechanisms, not learning processes.

Under SCE, teachers and other learning agents treat students as systemic cognizant beings (cf. §3.2 in Halloun, 2019) and follow SCE rules (§4 and Appendix) in structured *learning cycles* (Halloun, 2001, 2004/6, 2007) to efficiently manage all processes within suitable experiential learning ecologies and foster the development of specific and generic competencies that empower students with 4P profiles (output). Learning processes are mandated by the SCE framework, and cover all sorts of transactions and necessary exchange channels among various actors, whether conceptual (e.g., communication language and symbols, culture, ethics, and quality standards) or physical (e.g., syllabi, reports, project manuals and notebooks, computers, internet). They are carried out by learning agents whose 4P profiles are subject to continuous professional development.

3.3. SCE Taxonomy

Under SCE, we group the brain neural networks into six cerebral systems of six distinct broad functions. The systems are the relay system, the perceptual system, the motor system, the affective system, the rational system, and the epistemic system (Halloun, 2017a and 2019). These constituent systems are delineated so as to reconcile the actual morphology of the brain and the taxonomy of learning outcomes (LOs) that we have developed in our work in education (Halloun, 2017b). Our taxonomy classifies these outcomes along four multifaceted dimensions:

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

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

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

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

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

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

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

3.4. Critical thresholds

Various conceptual systems (e.g., scientific models) within the scope of any curriculum are at different levels of complexity from a structural, paradigmatic perspective, as well as from a cognitive, pedagogic perspective. The systems may thus be classified into sets of increasing complexity from both perspectives. At the lower end of the spectrum are systems that are most critical for students to develop meaningful understanding of course materials, especially at the epistemic level, and enough competence to start gradually relying more on their own than the teacher and other learning agents in the learning process. Such systems make up what we call the *core* part of the scope. At the upper end of the spectrum are *emergent* systems that students may be anticipated to develop almost independently of the teacher, should they have developed all other systems meaningfully.

A number of *thresholds* may thus be defined to delineate the boundaries between various conceptual systems in any field from paradigmatic and pedagogic perspectives. Such thresholds would set: (a) a paradigmatic hierarchy from a structural perspective, and especially (b) a cognitive sequence that should be followed in scope coverage from a pedagogical perspective. The most critical of these thresholds are the "basic threshold" and the "mastery threshold" (Fig. 5). The basic threshold separates *core* systems from *fundamental* systems (and related competencies), while the mastery threshold separates the latter from *emergent* systems.

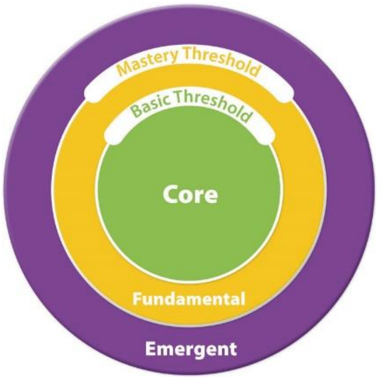

Figure 5. Critical thresholds in a given course.

In any course, core conceptual systems are the ones that allow students to develop, in simple forms, the most fundamental and critical conceptions and habits (content and process knowledge), and specific competencies which the curriculum is about. Fundamental systems are more complex systems in the context of which students reinforce, and widen the scope of, core conceptions and habits, and derive from them new conceptions and habits on the road toward generic competencies. Emergent systems may emerge from the composition of two or more core or fundamental systems, or may be entirely new and more complex systems, and require the development of more generic than specific competencies.

A student needs to meaningfully develop the *entire* set of core systems before s/he can proceed to fundamental systems. Any flaw in developing any conception or habit in the core set prevents the student from crossing the basic threshold, and thus from developing fundamental systems meaningfully. Students normally require significant teacher (and other learning agents) assistance in order to reach such threshold, especially at the epistemic level. Once students cross the basic threshold, the teacher can gradually retreat from the picture until students cross the mastery threshold. Beyond the latter threshold, students should be capable of developing the more complex emergent systems with the least teacher assistance ever.

Depending on the nature of a course and its contents, the three-level classification and the two critical thresholds defined above in relation to a number of systems in a given course may sometimes pertain to a single system in another course. In the latter case, core, fundamental and emergent parts of the course may pertain to particular systems that we call subsidiary systems or to conceptions of increasing complexity and habits necessary for their development.

For example, in Newtonian theory, two systems, the free particle model and the uniformly accelerated particle model, are most crucial for students to develop all Newtonian conceptions of translational motion, from state concepts to Newton's laws of dynamics (Halloun, 2001, 2004/6, 2007). The first model is a conceptual system that represents physical objects moving with constant velocity under no net external force. The second model is a conceptual system that represents physical objects moving with constant acceleration, i.e., with a velocity that varies with constant increments during equal time intervals. The two models make up the core part of any classical mechanics course. Once students meaningfully understand all Newtonian conceptions and develop sufficient competence to productively deploy these conceptions in the context of the two models in question, they reach the basic threshold and they become ready to gradually develop more complex particle models (the particle in uniform circular motion and the simple harmonic oscillator) and evolve towards the mastery threshold and beyond.

In any course, a teacher or textbook may often rely on subsidiary systems/models to introduce students to any new system/model. A *subsidiary system* is a particular instance of the target system which students may be familiar with, and that may facilitate the gradual development of that system. For instance, three particular cases of the uniformly accelerated particle model in Newtonian theory are usually distinguished in introductory physics courses, and each case may be introduced with a subsidiary model representing particular objects thrown near the surface of the Earth. As indicated in Table 1, the three cases are distinguished based on the initial conditions of motion (model scope), and more specifically the relative directions of two vectorial concepts: (a) the velocity ($\mathbf{v_o}$) of a particle like object at the instant one begins

Table 1

Subsidiary models of the uniformly accelerated particle model in the Newtonian theory of mechanics

Initial conditions of motion	**Trajectory**	**Speed**	**Subsidiary model**
$\mathbf{v_o}$ and **F** are parallel ($\theta = 0$)	Linear	Constantly increasing	Particle in free fall
$\mathbf{v_o}$ and **F** are opposite to each other ($\theta = \pi$)	Linear	Constantly decreasing until it becomes zero at which instant the object turns back to move along the same line with increasing speed	Particle thrown vertically upwards
$\mathbf{v_o}$ and **F** make an arbitrary angle θ different from zero and π	Parabolic	Constantly increasing if θ is right or acute; constantly decreasing otherwise until it reaches a minimum non-zero value at the top of the parabola at which instant the speed starts increasing	Particle thrown at an arbitrary angle with the vertical different from zero and π

$\mathbf{v_o}$ is the initial velocity of a particle like object at the instant one begins to explore motion.
F is the net constant force exerted on the object throughout its motion.
θ is the angle ($\mathbf{v_o}$, **F**) between $\mathbf{v_o}$ and **F**.

to explore the translational motion of the object, and (b) the net constant force (**F**) exerted on the object throughout its translation.

In some elementary physics courses, the content pertaining to Newtonian theory may be limited to one or two systems. For example, when that content is limited to the uniformly accelerated particle model, the core part of the course may consist of the subsidiary model representing physical objects that accelerate linearly in one specific direction like in free fall, the fundamental part, to the subsidiary model representing physical objects that accelerate linearly but that reverse direction along the same line (e.g., throwing an object vertically upward), and the emergent part, to the subsidiary model representing physical objects in parabolic motion on Earth or in space. In all three cases, the same Newtonian conceptions (concepts, laws and other theoretical statements) apply, but with increasing complexity, and some conceptions are added to complement the picture as we gradually move from the core to the emergent subsidiary models (like the superposition principle in the latter case).

4. Systemic provisions for sustainable meaningful learning

According to SCE, sustainable learning is best achieved under the following provisions (Figures in this entire section are referenced to those in Halloun, 2017a):

1. *Systemic controls*. The affective and rational systems that consciously control any learning experience (Fig. 8 and Fig. 9), and especially the critical affective system (CAS) and the prefrontal cortex (PFC) respectively in these two systems, work constructively in tandem so as to keep the entire experience systemically focused, from purpose to outcomes, and especially from perceptual image (PI) to conceptual image (CI), including the adduction of necessary information from the epistemic and other systems.
2. *Attention.* Attention is very critical for the new information to be filtered in ways to retain only salient or primary features, and induce the activation of association areas (Fig. 9). Furthermore, focused attention sharpens information filtered by the reticular activating system (RAS) that involuntarily governs our attention and consciousness, and allows retained information to be lean and free of any noise or redundancy. The better attention is focused, the leaner the filtered information and the more efficiently executive functions are engaged to pave the way for sustainable learning.
3. *Interest and motivation*. Focusing attention and shaping the course and outcome of information processing are determined by the affects, and especially the interests and motivation of the learner in relation to the long term purpose behind the learning experience. The more interested and motivated the person, and the more convinced of the need for that experience and of the value of its prospective outcomes to personal life, the more constructively CAS would intervene (especially its dopamine release system) to sustain various memory processes and to subsequently bring about sustainable outcomes.
4. *Lean focused purpose*. Focused and reasonable desired outcomes are clearly set ahead of time for any learning experience so as to avoid distraction and overload at any stage. This is best accomplished with a focus on aspects of objects of learning that would eventually lead to lean perceptual and cognitive images, i.e., images with the minimum primary details possible in both the real world and the mental realms, and free from all sort of noise and redundancy. Such lean images can lead to learning outcomes (LOs) that may be successfully integrated and sustained in LTM with affordable encoding and consolidation efforts.

5. *Perceptual image*. An object of learning (OL) is consciously explored as a system or constituent of a system conveniently delineated (Fig. 1) in accordance with the schema of Figure 2. This helps the relay system, and especially RAS, to focus attention on primary aspects of OL for the formation of the perceptual image (PI) and avoid overload with secondary details that are not pertinent to the experience at hand and that might even prevent primary details from making it through RAS in the first place, given the small fraction of information that RAS normally lets through for processing in the brain.
6. *Conceptual image*. The conceptual image (CI) is consciously constructed as a conceptual system or a constituent of a conceptual system that can be readily integrated with LTM patterns. The ability of the image in question to bring about meaningful and sustainable learning outcomes is primarily determined by how well it is encoded in dedicated cortical areas, and by how extensively it proliferates and how strongly it is consolidated in a variety of such areas.
7. *Encoding*. Encoding of a conceptual image in neural networks begins with the unimodal analysis of the perceptual image and continues through multimodal associations (Fig. 9). Unimodal encoding is localized in specialized or dedicated areas of the perceptual system, and multimodal associations can be spread across different cerebral regions and cortical areas, including specialized cortical areas and association areas. The choice of recruited areas depends on the ontology of OL and its intrinsic properties, as well as on the epistemology underlying the cognitive lenses via which it is being perceived. The more thorough and the deeper the encoding, the wider it spreads across the brain to engage a variety of dedicated and association areas and involve a multitude of representations of a given entity (OL or part of it) or relationship among entities, the more likely it will result in sustainable learning.
8. *Across-the-board associations and learning outcomes*. A learning experience of any type may engage some or all cerebral systems distinguished in Figure 8 and bring about learning outcomes along some or all of the four dimensions distinguished in Box 2, in both implicit and explicit LTM, even when the purposes of that experience are originally set to focus on one particular dimension. For example, exploration of an OL that is meant to figure out properties as simple as shape and color of such object (epistemic LOs) always involve some reasoning skills (rational LOs), e.g., differential analysis to tease out primary from secondary aspects of these properties, some perceptual and motor dexterities (sensory-motor LOs), e.g., focusing eyesight on particular components of OL and perhaps touching and handling the object in specific ways, and even some emotions about the object in question and the entire experience (affective LOs). A learning experience as simple as the considered exploration would practically involve, though to various extents, dedicated areas in all six cerebral systems and corresponding association areas. The extent to which any learning experience may lead to meaningful and sustainable LOs thus critically depends on how well various neural networks are insightfully engaged and consolidated.
9. *Adduction of prior knowledge and consolidation of distributed networks*. Sustainability of learning outcomes is ensured by the gradual consolidation of CI in LTM. This process that involves the adduction by PFC of appropriate content and process knowledge from LTM, and especially from the rational and epistemic systems, in order to properly transform the raw PI into a meaningful CI, and make it possible for emerging learning outcomes to be eventually inducted in LTM. The consolidation begins in the early stages of STM (WM, if conceived differently from STM as in Fig. 10), i.e., in making sense of the product of unimodal syntheses through proper encoding, and integrating this product in multimodal associations. Rich encoding in neural networks distributed across a variety of cortical areas with ample and strong multimodal associations among new networks and with prior

knowledge ensures not only the sustainability of emerging learning outcomes in LTM as mentioned above, but also the cognitive efficiency in ultimately retrieving these outcomes and deploying them successfully in novel situations.

10. *Rehearsal*. The transformation of STM into LTM requires the channeling of CI through the hippocampus (which may take days, even weeks, and is mostly achieved during sleep) and the strengthening of synaptic connections within and among neural networks in which the image has been encoded. The process, especially of strengthening connections, is significantly enhanced with repetitive retrieval of STM outcomes and rehearsal (deployment) in a variety of familiar and novel contexts, and subsequently the proliferation, consolidation and strengthening over time of the connections among concerned neural networks. Knowledge retrieval from STM, accompanied with retrieval of necessary content and process knowledge from LTM, is a dynamic evolutionary process. Knowledge retrieved from both memories undergoes transformation during retrieval and consolidation in ways that determine how meaningful and sustainable learning outcomes will be.

11. *Retrieval mnemonics and contexts*. When prior knowledge needs to be recalled for any reason, PFC specifies and activates necessary mnemonics to determine what knowledge needs to be retrieved and how to retrieve it and use it. Mnemonics are retrieval cues and processes that PFC develops during knowledge construction, and that determine the cognitive efficiency of the knowledge deployment. Mnemonics are often context related. They are most successfully deployed in the same or similar context in which they have been developed. They cannot be readily deployed in novel contexts without proper rehearsal and correspondence rules that facilitate transfer to those contexts. Mnemonics and rules are most effective when consciously and purposefully constructed in systemic perspectives, and when they concentrate particularly on cues emanating from the scope of a given system to determine where and when the system (or any of its constituents) can be deployed and for what purpose (§ 1, Fig. 2).

12. *Retrieval and memory development*. Any memory activation is a dynamic process that results in memory change (development). Knowledge retrieval (recall) from memory, like knowledge construction, is a conscious constructive process that induces changes in stored knowledge while it is being retrieved. The same is obviously true about putting retrieved memory networks into action (knowledge deployment). Changes in question are limited when retrieval takes place in familiar contexts and with the same mnemonics developed in parallel with memory formation. They become increasingly more significant with the level of novelty in new contexts. However, the cognitive efficiency of retrieval and deployment declines then unless explicit rules and processes are consciously developed for memory proliferation and consolidation, including related mnemonics (knowledge growth and deployment).

13. *Differential memory formation and retrieval*. Retrieving knowledge from memory follows different pathways than encoding the same knowledge in memory and involves cognitive processes that differ from those involved in memory formation (encoding, consolidation and storage). Furthermore, knowledge retrieval is a relatively fast process governed by mnemonics dictated by PFC, whereas knowledge induction in LTM is a long process governed by the hippocampus. The differential processes and controls in memory formation and retrieval can best be conciliated, and cognitive efficiency significantly improved, in systemic contexts with particular attention to the scope in the systemic schema.

14. *Differential outcomes consolidation and rehearsal*. Content and process knowledge, and different types of each (Box 2), are encoded in different cerebral systems (Fig. 7).

Consolidating and sustaining neural networks in which a specific learning outcome (LO) is encoded does not automatically consolidate and sustain related LOs of different types, even when all LOs correspond to the same OL/CI. Due attention paid in a systemic perspective to the consolidation and rehearsal of each LO separately and in relation to other LOs (through multimodal associations) ensures the consistency, coherence, and sustainability in LTM of all concerned LOs.

15. *Insightful regulation and metacognition*. The merits of CI, and especially the efficiency of encoding, consolidation, and subsequent rehearsal, are critically determined by the regulation, under the metacognitive control of the rational system and particularly PFC, of all processes and products from PI to CI. Regulation is most effective when it is carried out in insightful ways that make the correspondence lean and transparent between CI (and PI to start with), on the one hand, and OL and patterns in LTM on the other. Insightful regulation: (a) concentrates on systemic aspects of all entities and processes, (b) inhibits distractive processes, (c) filters out noise in CI coming from secondary and redundant information, (d) tightens up loose and fragmented information in that image, and (e) eliminates any conflict or incommensurability between CI and its real and mental counterparts. Insightful regulation is carried with the learner constantly aware that CI and arising learning outcomes are holistic products that emerge from the transaction between OL and learner. As a consequence, these products may be tainted with anomalies that may lead to permanent misconceptions and/or defective skills and dexterities in LTM if the regulation is not carried lucidly and critically enough in WM/STM and LTM, and properly monitored and kept on track by concerned metacognitive controls in the rational and affective systems, especially in PFC.

16. *Dynamic sustainability of LTM*. Memory patterns are dynamic. Sustainability is thus not a static state but an evolutionary state whereby memory networks may proliferate in ways that preserve their consolidated core structures and processes. Such a preservation implies that, unlike STM, content and process knowledge sustained in LTM cannot be easily "wiped out" and totally "forgotten". Some research even suggests that sustained LTM knowledge may not be wiped out from memory at all (Masson, Potvin, Riapel, & Brault Foisy, 2014). Should LTM knowledge consist of undesirable misconceptions or wrong or dysfunctional processes, proper inhibitory processes need then to be developed in PFC and the hippocampus to prevent their retrieval and activation.

17. *Brain-mind development*, or nature *vs* nurture impact on cognitive development. Biological development of the brain often determines whether or not a given conception, skill, dexterity, or affect (Box 2) can be encoded and/or processed at a certain age or stage of life in corresponding dedicated parts of our cerebral systems (Fig. 8). For example, PFC does not get fully developed, and particularly fully myelinated, until we are in our early or mid twenties, and even beyond for some people. Thus various sorts of abstract thinking and metacognitive controls that recruit executive functions in PFC cannot be conducted until these functions are brought to maturity, some at early school age and most others subsequently and through various stages of adulthood. This, of course, somewhat rhymes with Piaget's stance on cognitive development that brain biological development is a prerequisite to learning and mind conceptual development. In contrast, there are instances where the opposite stance held by Vygotsky holds that learning is a prerequisite to brain development. Such is the case, for example, with the visual word form area located within the fusiform gyrus of the occipital lobe of the cerebral cortex. This area gets biologically developed as we learn to read, and becomes increasingly specialized with the processing and recognition of written letters and words.

References

This working paper consists mostly of excerpts from documents by the same author listed below. Interested readers are invited to check out these documents for ample details about various parts of the paper, especially about systemism, systems, and models, brain systems and memory formation, competencies, and learning outcomes. Documents in question may also be checked for cited references other than those by Prof. Halloun and listed below.

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Appendix

Systemic Cognition and Education

Toward a systemic MBE-based pedagogical framework

A pedagogical framework is a conceptual system that governs the design and deployment of particular curricula in formal education, and that may be defined in accordance with our systemic schema (Fig. 3) as follows:

1. *Foundations* (rather than "Framework"). Premises derived from reliable findings in pertinent research about: (a) human biological and mental development, (b) paradigms of related academic fields, and especially corresponding epistemology, and (c) successful practices in related professions. Framework foundations also stem from local culture and vision for society and various production sectors.
2. *Scope.* Design and deployment of a specific curriculum or, ideally, a set of curricula which the same students may follow concurrently or at different times in their lives in order to gradually develop a given profile.
3. *Constitution.* Cognitive tenets and principles for the design and management of curriculum materials in an appropriate learning ecology.
4. *Performance.* Rules of engagement with appropriate practice protocols and other guides for optimizing the management and output of the learning ecology within the broad educational system, and for translating the desired profile into appropriate learning outcomes for specific and/or cross-disciplinary fields at particular school age/level.

In the following, we concentrate our discussion on the most practical premises of a pedagogical framework. These premises pertain to framework constitution and performance. They include cognitive tenets, pedagogical principles, and operational rules that must be respected in devising and implementing every component of the governed curriculum or curricula, from programs of study to means and methods of learning, instruction, assessment, and evaluation. The premises in question, and particularly tenets and principles, are first outlined in a generic form, and then as they relate to Systemic Cognition and Education (SCE.

1. Tenets

Tenets are universal statements of axiomatic nature that lay down the common foundations for all other premises and practices, at all educational levels. They are mostly of cognitive nature, and govern profile definition and development, and thus the specification of realistic outcomes anticipated at specific school ages, along with corresponding programs of study and various other curriculum materials. Among others, tenets stipulate the following:

1. *Learning potentials and human development*: What a learner *can* do, from cognitive and behavioral perspectives, given biological development of certain brain regions and body parts, and what s/he *should* do to promote biological and functional development of these and other cerebral and bodily components.
2. *Patterns of success*: What cognitive and behavioral patterns of accomplished professionals can learners emulate and embody in their profiles.

3. *Meaningful and sustainable learning*: What constitutes meaningful and sustainable learning and what cognitive processes consciously promote such learning in long-term memory.
4. *Metacognitive controls*: What affects and reasoning skills sustain purposeful attention and ensure insightful regulation and constructive processes and outcomes, and what cognitive incentives promote the development of such controls.
5. *Learning ecology*: What profile human agents should have, what conditions physical agents and surroundings should satisfy, and what should govern learners' interaction with them all, in order to optimize learners' profile development.
6. *Measurement*: What conceptual and physical processes and outcomes can reliably ascertain the actual state of learners' mind and brain.

Our position in the above respects can be partially summed up in the following points that are taken into consideration in the formulation of SCE tenets:

1. The mind and brain of any person are in continuous evolution governed by intrinsic and external factors and induced intrinsically through self-regulation or provoked externally through interaction with other people and the physical world.
2. There is an interplay between brain and mind development such that the more we consciously and purposefully learn, the better our brain gets wired (and the "smarter" we get). However, the natural potentials of working memory (WM), short-term memory (STM), and long-term memory (LTM) may impose certain limits on the thoughts and actions that any learner is capable of at a specific school age.
3. Sustainable learning in LTM gradually gets decontextualized, from early and primary school ages where learners rely more on perceptual information to consolidate their memory, to secondary and even tertiary education where learners become more and more capable of relying on their own conceptual realm.
4. Meaningful and sustainable learning requires long-time rehearsal of new knowledge in familiar and novel situations that are challenging enough to motivate but not discourage learning.
5. Knowledge construction (encoding, consolidation, storage) and deployment (even when limited to retrieval and rehearsal) engage distinct neural pathways and cognitive controls, and thus impose different cognitive demands and require different cognitive strategies.
6. Different types of learning outcomes are encoded in different parts of the brain, and require different construction (and deployment) strategies even when they pertain to the same object of learning.
7. Coherent and lean organization reduces the cognitive load in encoding and consolidating new knowledge in STM, and improves the likelihood of subsequently storing it in LTM, and eventually of successfully retrieving it with appropriate mnemonics for deployment in new situations. Systems provide in this respect the optimal conscious organization schemes.
8. Learning outcomes brought about in experiential learning emerge from holistic processes that involve realist-cognitive transaction between objects of learning (OL) in their details and wholeness and learners' own bodies and brains, especially their perceptions, conceptions, and thoughts.

9. Learner-OL transaction is most effective and efficient when consciously conceived for systemic purposes, and governed by systemically driven and focused, insightful, and constructive metacognitive controls.
10. Transaction with an object of learning involves reiterative cycles for the cognitive deconstruction and reconstruction of the object. Each cycle begins with the formation of a partial perceptual image of the object and ends with the formation of a corresponding conceptual image or a refinement of such image when already in STM. For cognitive efficiency purposes, learners should focus their attention on primary details that would make up a lean conceptual image of that object by correspondence to corresponding patterns in the real world and in the learner's prior knowledge in LTM.
11. There are universal patterns in humans' mental realm, just like in the physical world. Mental patterns that are most meaningful for success and excellence in modern life are those reflected in the 4P profiles of accomplished experts in different professional communities.
12. The profile of an ordinary person evolves meaningfully and efficiently when it recapitulates the historical development of academic paradigms and the profile evolution of accomplished experts, and when it becomes gradually commensurable with modern paradigms and expert profiles in insightful and experiential ways.
13. The ontology of a person's mind and brain can be neither directly nor exhaustively measured in classroom settings. It can only be indirectly and partially ascertained through the person's conceptions, reasoning skills, dexterities, and dispositions revealed in appropriate learning/assessment tasks.
14. Human learning agents, and especially teachers, are critical agents of profile change and not conveyors of canned academic knowledge.

2. Principles

Pedagogical principles are stipulations emanating from the tenets and corroborated by related research especially in educational cognition and psychology. They specify viable (valid, reliable, effective) learning processes that contribute to meaningful profile development under a variety of educational settings, and set the design of the appropriate learning ecology (i.e., its structure, as opposed to respective operations mandated by corresponding rules). Among others, pedagogical principles stipulate the following:

1. *Learning habits*: What learning habits need to be developed for lifelong learning and gradual development of a target profile (4P profile in SCE) in relation to specific academic fields.
2. *Evolution tracks*: What paths can learners follow in order to gradually and successfully develop the desired profile.
3. *Programs of study*: What taxonomy of learning outcomes helps best translate the profile into learning outcomes that can be attained at specific age and points of instruction, and what sort of programs of study can coherently bring together the specified outcomes.
4. *Teaching schemes*: What learning activities can best allow individual students develop the desired learning habits and evolve toward the target profile, and what instructional practices are most suitable to these ends.
5. *Learning ecology setup*: What settings (facilities and resources included) need to be in place (within and outside the school), and what criteria these settings need to satisfy

separately and in putting them together at the disposal of learners working individually and collectively.

6. *Authentic assessment*: What schemes are needed in order to make assessment an integral part of learning and instruction, and, to this end, viably ascertain the extent to which individual learners have attained specific learning outcomes at specific points of instruction, and evolved along the desired tracks.
7. *Evaluation and regulation*: What measures need to be taken to evaluate the feasibility of various aspects of the curriculum (from programs of study to teaching practices) in bringing about the desired outcomes, and subsequently to reinforce effective aspects and fix deficient aspects.
8. *Axiology*: What measures need to be taken in order to ensure that all products and processes respect specific values and ethics, and resonate well with cultural norms and justified individual and collective aspirations.

Our position in the above respects can be partially summed up in the following points that are taken into consideration in the formulation of SCE principles:

1. In order to develop dynamic 4P profiles that can be readily adapted to continuously changing needs of our modern life, students should develop systemic learning habits that are consciously driven for the exploration of universal patterns with systemic lenses and the construction and deployment of representative conceptual and physical systems.
2. For effective profile evolution, and meaningful and sustainable learning, students of all age groups should be guided to become consciously aware of the potentials and flaws in their own profiles, transcend their naïve and obstructive traits, and insightfully regulate their defective skills, dexterities, and conceptions.
3. For curricula to be effective, they should not come in one-size fits all. They should be flexible enough to account for cognitive and behavioral differences among learners of the same age group, and cater for the same learner to the distinctive cognitive needs imposed by different dedicated cerebral parts where learning outcomes of different types are encoded.
4. Formulation of a program of study, design of the appropriate learning ecology, and the choice of all curriculum materials, should respect cerebral and mental potentials of individual learners at specific age and points of instruction and not impose cognitive loads that are beyond these learners' potentials.
5. Programs of study should come with, and promote, a universal schema for the organization of all sorts of knowledge in the form and the context of systems in order to foster meaningful and sustainable learning with the least cognitive load possible.
6. Programs of study should come explicitly in middle-out designs around lean discipline-specific and cross-disciplinary systems that reveal particular patterns in the real world and/or in the conceptual realm of academic paradigms.
7. No conception should be included in a program of study solely for its own sake, but more importantly for the purpose of constructing and deploying a particular system or set of systems.
8. A cross-disciplinary system should have a structure that brings together conceptions from different disciplines, and is constructed and deployed in tasks requiring cross-disciplinary competencies, i.e., clusters of learning outcomes pertaining to specific and generic

conceptions, skills, and dexterities in these disciplines, and across-the-board affects and metacognitive controls.

9. Programs of study should systematically translate the target profile into learning outcomes corresponding to each system or set of systems in the program, in accordance with a well-defined taxonomy of conceptions, reasoning skills, dexterities, and affects, and follow an outcomes' progression within and among systems that matches the normal cerebral, mental, and bodily development of humans during school years.
10. Learning and instructional processes devised for the construction of specific learning outcomes should be different from those devised for the deployment of those same outcomes, and different processes should be in place for different types of learning outcomes pertaining to the same type of objects of learning (same system or pattern). Nevertheless, a generic structured strategy, like "learning cycles", may be adopted for designing and deploying lesson plans.
11. Learners should be made consciously aware of the cognitive processes and metacognitive controls involved in the development of new knowledge, and particularly of the PI-CI cycles that bring about desired learning outcomes.
12. Learners should become aware that, because of perceptual and cognitive limitations, conceptual images they develop of objects of learning are prone to errors, and that these images and related knowledge they hold in memory need to be constantly and consciously evaluated and insightfully regulated by correspondence to the real world and the conceptual realm of academic paradigms.
13. For effective and efficient insightful regulation, learning strategies should be developed that recapitulate the history of human evolution and development of academic paradigms, especially with regard to the emergence of erroneous ideas and their successful regulation.
14. For effective and efficient learning, learners should be helped to:
    a) become consciously aware of the limited capacity and span of attention in STM (or WM) in experiential learning;
    b) engage in experiential learning not only hands-on, but most importantly minds-on with systemic metacognitive controls;
    c) develop constructive metacognitive controls that keep their attention focused with a systemic perspective on primary aspects of any object of learning that help bringing about a lean perceptual image of that object;
    d) deeply encode the reconstructed perceptual image (following unimodal analysis and synthesis) in well-coordinated multiple representations in various cortical areas;
    e) convincingly follow structured learning strategies like learning cycles.
15. For meaningful and sustainable learning, learners should be helped to consciously:
    a) develop a rich, but lean and coherent panoramic conceptual image of any object of learning that involves, to the extent that is possible, representations from a variety of academic fields;
    b) conceive that image as a conceptual system that partially represents the object in question;
    c) consolidate that image with prior knowledge in LTM, and insightfully regulate any possible inconsistency with and within that knowledge;
    d) develop desired learning outcomes in a variety of contexts involving the same, similar, and different learning objects;

e) develop appropriate mnemonics that would subsequently allow the efficient and successful deployment of these outcomes in any novel situation;

f) develop appropriate rules of correspondence that would subsequently facilitate the transfer of any knowledge developed in a particular academic field to other fields.

16. For meaningful and sustainable learning to be possible to achieve, learners should be:

    a) convinced of the conceptual and practical need for, and merits of, what they are required to learn;

    b) engaged in the design of necessary learning tasks so that they assume ownership of these tasks, and be intrinsically motivated to carry them out with passion, enthusiasm, and perseverance, and bring them to constructive and fruitful ends.

17. Learning and instruction should rely on a variety of authentic assessment tasks that allow assessment "of" learning, "for" learning, and "as" learning.

    a) Authentic assessment "of" learning is meant to reliably ascertain, in the context of a given system or set of systems, the extent to which individual students have:

        i. achieved particular learning outcomes and met the expectations set in the target profile at specific points of instruction;

        ii. adequately followed anticipated progress or evolution paths throughout the course of instruction.

    b) Authentic assessments "for" learning is meant to:

        i. allow students explicitly develop their metacognitive controls and insightfully regulate their own profiles;

        ii. allow teachers track and regulate the evolution of individual students' profiles along the desired paths in efficient and meaningful ways;

        iii. evaluate and efficiently regulate instructional means and practices, and the entire learning ecology;

        iv. contribute to the refinement/reform of the curriculum and the entire educational system.

    c) Authentic assessment "as" learning considers every assessment task a learning task whereby learners do not simply retrieve ascertained content and process knowledge from memory and deploy it exactly as it used to be stored there, but they actually regulate and change retrieved knowledge in the process of adapting it to the task at hand.

18. Curricula should be implemented by systemic teachers who are trained to act as critical agents of systemic profile development and not as conveyors of curriculum materials, and who, to this end:

    a) come with reasonable expectations about what their students can do at any given point of instruction, and what they can do to help students attain desired learning outcomes;

    b) systematically scaffold academic knowledge, preferably through experiential learning activities, using systemic schemes (operational plans and procedures) and schemata (structural templates like the systemic schema of Figure 2) that resonate well with the morphological and phenomenological patterns of the brain;

    c) carry out their mission flexibly, and adapt various curricular aspects to individual students' needs, from programs of study to the means and methods of learning, instruction, and assessment.

3. Rules

Operational rules are procedural statements or pedagogical guidelines that specify how various operations need to be carried out by learners and agents within the learning ecology, and what physical and operational conditions need to be satisfied by various aspects of a curriculum, for efficient profile development in accordance with the stipulated tenets and principles. These rules should come with prescriptive protocols that provide explicit instructions on learner transactions with objects of learning and learner-agent interactions. They should also come with specification criteria or standards and corresponding indicators, design templates, and management rubrics for all physical settings in and around the learning ecology, from course resources, classroom layout, and school facilities and services, to school environment and the educational system at large.

In the following, we provide a non-exhaustive list of curriculum aspects for which operational rules and necessary protocols and/or other guides need to be formulated, without going into the details of our position regarding these matters, which is far beyond the scope of this paper. We just mention here that, for optimal results, rules and guides need to be formulated in a systemic perspective whereby every entity, whether human or not, is conceived as a system or constituent of a system which, in turn, may be part of a more complex system. These systems may go in scale from a given classroom in a given school to a national educational system, and they all operate for a common broad outcome: bringing up students with suitable 4P profiles. Proper structure and operation of all these systems require operational rules and guides that cover among others the following aspects:

1. *Educational system*:
   a) How the entire educational system should be structured and governed.
   b) What value system should govern all actors and practices.
   c) What monitoring and support systems need to be in place for various human agents, and how these systems should be operated and constantly evaluated.
   d) How the entire system should be constantly evaluated and refined.
2. *Cross-curricular convergence*:
   a) How to bring coherently together various curricula followed by the same students during a given school period (typically a given cycle).
   b) How to make curricula of different levels consistently follow from each other under the same tenets and principles in the direction of bringing about graduates with 4P profiles.
3. *Schools and their communities*:
   a) How schools should be designed and governed.
   b) What facilities, services, and resources they should provide, and following which standards/criteria.
   c) What leverage schools have in adapting various aspects of a curriculum to the actual needs and aspirations of their students and communities, and how they should go about doing that.
   d) How they should interact with various sectors in their communities, and what sort of partnerships they should forge with particular educational and non-educational institutions.
4. *Learning management*:
   a) How lessons should be planned, learning activities designed, and all flexibly implemented to cater to actual student potentials and needs.

b) How structured experiential learning should be, and how “learning cycles” can come handy in the process.

c) How various types of assessment should de designed and implemented.

d) What physical settings, and especially technological means, are necessary to each task, and how they should be managed.

e) How leaners should interact with each other and with teachers, and what communication, exchange, and feedback channels should be maintained among them.

f) How should learning and instruction be evaluated and results extrapolated.

g) How students and teachers should interact with various other stakeholders.

5. *Professionalism and accountability*:

    a) How teachers and various other human agents should behave and continuously enhance their practices.

    b) How they should be engaged in appropriate professional organizations, how they should contribute to educational research and development, and what incentives they should be given to these ends.

    c) How their actions should be monitored, evaluated, and duly compensated.

6. *Curriculum refinement*:

    a) How pertinent MBE research findings and classroom practice should be conciliated.

    b) How curriculum deployment should be monitored and evaluated in various schools, and how it should be subsequently refined.