Profile Shaping Education

An Overview

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Abstract:

Profile Shaping Education (PSE) is a novel, research-based pedagogical framework that promotes a particular 4-P profile (Paradigmatic, Productive, Proactive, Principled) meant to empower students for meaningful learning rather than rote learning of course materials, and for success in modern life rather than for merely passing school or high-stake exams. The profile is reified in cross-disciplinary curricula in the form of learning outcomes that are defined according to a novel taxonomy of learning expectations. The taxonomy focuses on patterns in knowledge structure and habits of mind and practice that are common to accomplished professionals in various fields. Learning outcomes in every field are spelled out accordingly in four dimensions (epistemic, cognitive, behavioral and metacognitive) in the context of a limited number of systems that best reflect those patterns. Students gradually develop various outcomes while systematically engaged in experiential learning cycles that are teacher mediated for efficient and insightful regulation of individual students' profiles. Authentic assessment "for" learning and not "of" learning is uniformly carried out in various educational fields to guide teacher mediation.

This paper is based, in part, on the following publications:

Halloun, I. (2012). Taxonomy and Learning Outcomes in Profile Shaping Education. Proceedings of the conference on *Education Sustainability.* Dubai, UAE: ACES.

Halloun, I. (2011). From modeling schemata to the profiling schema: Modeling across the curricula for Profile Shaping Education. In Khine & Issa (eds). *Models and Modeling in Science Education.* Boston, MA: Springer.

Halloun, I. (2011). Profile Shaping Education: A paradigm shift in education to empower students for success in modern life. *Proceedings of the 11th International History, Philosophy and Science Teaching Group biennial conference,* pp. 337-343. Thessaloniki, Greece: IHPST.

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

Halloun, I. (2004/2006). *Modeling Theory in Science Education.* Dordrecht: Kluwer Academic Publishers / Boston: Springer.

Halloun, I. (2001). *Apprentissage par modélisation : La physique intelligible*. Beyrouth : Librairie du Liban Publihers.

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Profile Shaping Education (PSE) is a generic, research-based pedagogical framework developed in part under the auspices of Educational Research Center (ERC). The framework sets to empower students of all levels, especially secondary school and college graduates, with a profile needed for success in modern life. The profile embodies major traits of accomplished people in the workplace and daily life, and its reification according to PSE is done in ways that respect the local vision for education and local culture and heritage.

This paper presents, in nine sections, a quick overview of PSE. It begins with an inventory of major scholars whose significant and constructive contributions to education and the development of human thought are accounted for in PSE. The PSE pedagogical framework is outlined in Section 2, and the profile it advocates in Section 3. Section 4 highlights how the scope of any field can be set, with attention to cross-disciplinarity, around a limited number of systems that may be ordered or leveled, as discussed in Section 5, according to well-defined paradigmatic and pedagogic criteria. Section 6 offers a novel taxonomy that helps translating the 4-P profile into four types of learning outcomes (or any other type of learning expectations). Profile and outcomes that evolve in four stages outlined in Section 7 can best be reified in the classroom, according to PSE, in mediated experiential learning cycles (Section 8) that are guided by authentic assessment (Section 9). At the end (Section 10), the paper directs readers to major ERC initiatives that put PSE into practice.

1. PSE background

PSE draws on research in education, cognition (neuroscience included), and philosophy, sociology and history of various educational fields. It especially draws on corroborated aspects of modern educational theories, and mostly on modeling theory in science education developed by this author. The following are just a few among the many scholars whose work had a touch on PSE:

- Bernard, Bachelard and Kuhn, and their work on what Bachelard calls epistemological profiles and what Kuhn calls paradigms, and especially on differences between ordinary people naïve or novice profiles or paradigms and professional or expert profiles or paradigms (mainly scientific), and on barriers that may prevent the positive evolution of all sorts of paradigms or profiles.
- Wertheimer, Perry, Covey, and scholars working on psychological traits, the works of whom point out major personality traits needed for success in modern life.
- Reif and others who worked on delineating differences between novices (students) and experts in the educational realm, especially in knowledge structure and problem solving.
- Wartofsky, Bunge, Johnson-Laird and all other philosophers and cognitive scientists who showed, along with Lakoff, how crucial models and other conceptual systems are in the organization of human thought.
- Lakoff and his work on the categorization of human knowledge, especially in relation to what we call middle-out knowledge structure.
- Galileo, and his rules for transcending common sense to come to objective and viable knowledge about the world, rules that were further developed and somewhat complemented by the works of Huygens, Descartes, Newton and ... Einstein.
- Dewey and Piaget, and their call for autonomous construction of knowledge and self-evaluation and self-regulation for resolving internal conflict within one's own knowledge and incommensurability with expert knowledge. All this may best be achieved in an experiential approach, as and first introduced in Dewey's "transaction" and later discussed by Lakoff.

- Socrates, and the way he engages people in dialogues that allow them, as demonstrated by Plato, to reflect on their own knowledge and meaningfully construct new knowledge.
- Gardner and Bruner, and how their work shows that all students can excel in learning when teaching is flexible enough to account for students' different learning styles (along the lines of so-called "multiple intelligences").
- Karplus and colleagues who demonstrated, somewhat in harmony with Gagné, the merits of learning in structured learning cycles.
- Vygotsky, and his work on the zone of proximal development that shows the importance of teacher intervention at different levels in the learning process.
- Gagné and Bloom, and the importance they attribute to well-defined taxonomy for the classification of educational objectives.
- Seminal works on: (a) prominent educational theories, like information processing theory, conceptual change, and 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), outcomes-based education and European qualifications, to list a few.

2. PSE framework

PSE offers a generic pedagogical framework that may be used in the design of any educational curriculum and the deployment of either or all practical aspects of a curriculum, from program of study to methods and means of learning, instruction and assessment (Figure 1). The framework consists of a set of tenets, principles and rules that govern the development of student profiles which various communities can define to best suit their needs. It also includes a unique taxonomy of learning expectations that helps translate a target profile into reifiable learning outputs of any type.

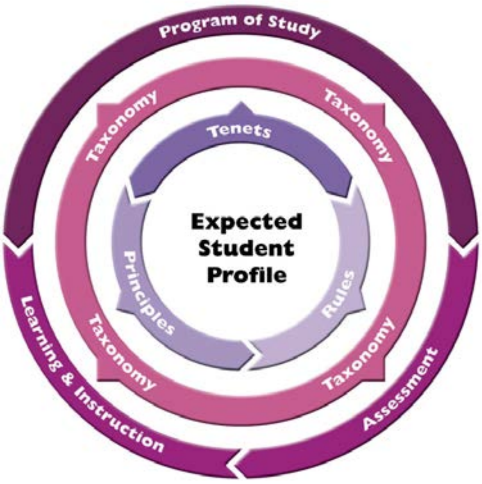

Figure 1: PSE Framework.

PSE tenets are universal statements of axiomatic nature that lay down the common foundations for all types of educational premises and processes, at all educational levels. They are mostly of cognitive nature, and govern profile definition and development, as well as the statement and deployment of pedagogical principles and rules. There are five tenets in PSE outlined in Figure 2. As can be noticed in this figure, PSE tenets primarily assert that: (a) professionals, especially those in academic communities, share common expert paradigms for knowledge construction and deployment, and (b) that there are patterns in the structure of expert paradigms and practice of accomplished professionals in various communities. PSE subsequently calls for education to systematically empower students with profiles that recapitulate such patterns.

An expert paradigm consists, for us, of: (a) foundational premises (e.g., tenets, principles and rules) that govern development and deployment of (b) generic processes and habits (skillful mental and manual processes and dispositions) and (c) episteme (a coherent repertoire of conceptions or conceptual knowledge which, say in science, makes up a corroborated scientific theory or set of such theories), all of which being accepted and shared by a community of professionals.

PSE Tenets

Tenet 1: Evolution of the human mind

The mind of any person is in continuous evolution that may be induced intrinsically (spontaneous engagement) or provoked externally through interaction with other people and the physical world (eco-engagement), and that is governed by intrinsic and external factors.

Tenet 2: Mind and profile

The ontology of a person's mind can be neither directly nor exhaustively determined. It can only be indirectly and partially ascertained through a particular four-dimensional profile inferred from the person's acts and expressions (i.e., behavior). The profile consists of what people (and even the person in question) think are the person's conceptions, reasoning skills, dexterities and dispositions.

Tenet 3: Patterns of success in modern life

There are universal ontological 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 profiles of accomplished experts in different professional communities.

Tenet 4: Meaningful profile evolution

The profile of an ordinary person evolves meaningfully and efficiently when it recapitulates the profile evolution of accomplished experts, and becomes gradually commensurable with expert profile in insightful and experiential ways.

Tenet 5: Cognitive ecology and its management

Profile evolution, like mind evolution, is governed to a large extent by the available cognitive ecology, which includes immediate and remote, intrinsic and external factors that need to be propitiously controlled or diffused for the evolution to proceed efficiently and meaningfully.

PSE Principles	PSE Rules
1. Generic framework of lifelong learning	1. Educational system
2. From student profile to expert profile	2. Educational institutions
3. Middle-out, system-based cross-disciplinarity	3. Theory, practice and professionalism
4. Taxonomy & learning progression	4. Instructional management and communication
5. Learning cycle	5. Systemic monitoring and sustainability
6. Learning management	6. Partnerships & community engagement
7. Authentic assessment	
8. Pedagogy and technology	
9. Pedagogy, culture and axiology	

Figure 2: Outline of PSE premises.

PSE principles are corroborated pedagogical statements that describe or explain specific viable (valid, reliable, efficient) educational processes that contribute to meaningful profile development and that may apply to a variety of educational settings. Each PSE principle consists of three parts covering respectively: (a) how students learn, (b) how teachers should help students learn, and (c) what profile teachers should have already developed, and continue to develop through continuous professional development, in order to succeed in their task. There are nine principles in PSE that spell out how to set the content of any course and how to design learning experiences and classroom environment that empower students with a profile for success in modern life (Figure 2).

PSE rules are procedural statements or pedagogical guidelines that prescribe how specific processes need to be carried out, inside and outside the classroom, and what physical and procedural conditions need to be satisfied, for efficient profile development in accordance with PSE tenets and principles. In particular, PSE rules provide specific instructions for the design and management of the entire learning ecology, from classroom and school resources to school environment and the educational system at large, so that various mechanisms (means and methods, settings, protocols) of learning, instruction and assessment may be properly designed and efficiently carried out (Figure 2).

3. The 4-P profile

Research shows that there are patterns in both knowledge structure and practice of accomplished professionals in the workplace. Patterns in knowledge structure are reflected in the make-up of individual expert paradigms, and, most importantly, in the way these professionals relate different paradigms within the same field and even across different fields. Patterns in practice extend from systematic paradigm construction and deployment, and insightful regulation of one's own paradigms and practice, to constructive, efficient and considerate interaction with others. As such, accomplished professionals are all paradigmatic, productive, proactive and principled. These common four traits make up the 4-P profile which PSE endeavors to empower students with for success in modern life (Figure 3).

A ***paradigmatic*** student realizes that knowledge construction and deployment in every profession are governed by certain paradigm(s) in line with which s/he needs to develop her/his own profile. For efficient transcendence of personal paradigm(s), the student concentrates on a balanced and comprehensive repertoire of foundational and generic episteme and cross-disciplinary habits of mind that allow her/him to realize the big picture within and across disciplines.

Figure 3: The 4-P profile.

A ***productive*** student relies on systematic ways and means, cognitive and technical, for meaningful development and constructive deployment of conceptions and mental and behavioral habits within each discipline, and for productive and creative extrapolation of conceptions and habits into other disciplines and everyday life.

A ***proactive*** student adopts a clear vision of her/his education and future, and develops an affinity for detecting and resolving problems, and for anticipating new challenges and coping with them. The student continuously seeks, and assumes control of, new learning experiences in order to evaluate and regulate her/his own profile. S/he constructively engages with others to help them do the same, and subsequently to empower self and others for lifelong learning and continuous profile development.

A ***principled*** student embraces positive dispositions, especially those that characterize her/his own culture and expert paradigms, and interacts conscientiously, respectfully and constructively with others and the physical environment.

4. Middle-out, system-based cross-disciplinarity

According to PSE, patterns in the realm of expert paradigms are best manifested through conceptual systems, just like patterns in the physical world manifest themselves in the structure and behavior of physical systems. A *physical system* is a set of interacting material bodies that reflects a particular *pattern* in the structure and/or behavior of the real world (e.g., an atom, the human cell or nervous system, the solar system, or a social system). A *conceptual system* is a set of interacting mental or abstract entities that reflects a given *pattern* in the epistemic realm of a given profession (e.g., a narrative text, a scientific model or theory, an economic model or theory, or the constitution of a country).

According to PSE, every conceptual system has a well-defined scope and structure, the construction and deployment of which require certain habits. The *scope* dimension specifies the *domain* of a system (what pattern the system represents in either the physical world or conceptual realm) and its *function* (what the system is good for, and under what conditions). The *structure* dimension specifies the *composition* of the system (what primary entities the system consists of, and what are their salient properties), its *internal structure* (how these elements and their properties are related to each other within the system), and its *external structure* (how the system relates to its environment and/or other systems within and outside the confinement of its paradigm).

Figure 4 shows four systems from different fields outlined in the form of epistemic and cognitive benchmarks (broad statements of reference). Each cell in the four instances is partially filled with a sample of benchmarks that are required in typical systems covered at the secondary school or college level. The reader can easily realize that *epistemic* cells include particular information or theoretical statements (conceptions) about the scope or structure of a given system that are commonly accepted by the concerned community of professionals (scientists, mathematicians or linguists, in the case of our example), and that the student is expected to "*have*" at a given point of instruction. In contrast, the reader can readily realize that *cognitive* cells include what the student is expected to "*be*" capable of doing at that stage, and this in the form of habits (mostly reasoning skills) which the student is expected to develop in the context of a given system, but which are generic enough that the student can deploy them in the context of any other system.

Conceptual systems are at the center of what we call *middle-out* structure of expert paradigms in any academic field. These systems are in the "middle" of conceptual hierarchy, between the big epistemic picture and concept, and more specifically, say, between theory and concept in science or between text and word in language. A conceptual system in science, and more specifically a scientific model, is to theory and concept what an atom is to matter and elementary particles. Each elementary particle is essential in the structure of matter, but its importance cannot be conceived independently of its interaction with other particles inside an atom. It's the atom and not elementary particles that gives us a coherent and meaningful picture of matter, and it's the atom that displays at best the role of each elementary particle in matter structure. The same goes for language. A paragraph is a conceptual system that stands in the middle between text (narrative, argumentative, or any other type) and word, and that gives us a coherent and meaningful picture of any type of text, while it displays at best the role of each type of words in the text.

System: Bohr's Atomic Model		Episleme	Sample habits
Scope	**Domain**	Hydrogen atom and hydrogen-like (or hydrogenic) ions.	Criterial reasoning and differential analysis whereby: (a) a pattern is defined among hydrogenic atom/ions that may be classified together and distinguished from many-electrons atoms or ions, and (b) the appropriate theory is chosen to construct and deploy the Bohr model (e.g., the classical theory governing the so-called standard model).
	Function	Description and explanation of a limited number of aspects of a single electron bound on a fixed orbit assumed to be circular.	Logical and critical reasoning by virtue of which particular questions are specified that the Bohr model may answer, to certain limits, about hydrogenic atom/ions, in the context of the chosen theory. Exploratory analysis to set what the model can specifically describe and explain about hydrogenic atom/ions.
Structure	**Composition**	A nucleus with one proton (hydrogen) or more (hydrogenic ions), and a single electron. Properties of interest include mass and charge of these entities, and state properties of the electron (e.g., velocity).	Differential analysis by means of which specific (primary) entities (electron and nucleus) and object and state properties are exclusively included in the model, and other (secondary) entities and properties are left out.
	Internal Structure	Interaction between the nucleus and the electron partially represented by a central binding force (Coulomb interaction) exerted by the proton(s) in the nucleus on the electron.	Criterial reasoning to establish the structure, say in the context of classical theory, by analogy to planetary models (e.g., Earth-Moon system in the solar system). Relational reasoning to establish relations between primary properties of various entities in the form of state, interaction and causal laws; and representation dexterity to express those laws algebraically, graphically…
	External Structure	Interaction between a hydrogenic atom/ion and other neighboring atoms (molecular structure), or other types of environment (e.g., electro-magnetic field).	

Figure 4a: Sample benchmarks associated with Bohr's atomic model in physical sciences.

System: Quadratic Function		Episleme	Sample habits
Scope	**Domain**	A polynomial function that models co-variation between an independent variable (argument) and a dependent variable (image or function value) that is a sum of monomials in the independent variable with a leading term of the second degree.	Differential analysis, along with criterial reasoning, allowing the distinction between functions and other relationships, and the classification of certain functions as quadratic.
	Function	In mathematics, associating two changing objects, or specifying processes that transform one object into another, such that the value of one is the sum of monomials in the other with a leading term of the second degree. In science, describing or explaining the state or change of state of a system whereby a given descriptor relates to another proportionally, and to the second power.	Logical and critical reasoning by virtue of which particular questions are specified that the quadratic function may answer, to certain limits, about certain co-variation between two variables and/or the state of certain physical systems. Exploratory analysis to set what the function can specifically tell about the co-variation, or describe or explain about the system state.
Structure	**Composition**	One independent variable or descriptor of specific admissible values (argument, x), one dependent variable or descriptor (function, y), and constant coefficient(s).	Differential analysis by means of which specific entities (variables and coefficients) are identified, and others excluded (e.g., non-admissible values of x, variable coefficients).
	Internal Structure	The general algebraic form relating various components is: $y = ax^2 + bx + c$. Graphically, parabola depict quadratic functions. Co-variation between the two variables x and y is further specified with the first and second derivatives (rate of change) of y relative to x.	Relational reasoning to establish the functional relationship between the two variables, along with exploratory analysis to extrapolate to derivatives and integrals. Logical reasoning to infer certain conclusions from symmetry, derivatives, tangents, concavity, etc. Communication dexterity to properly depict various aspects of the function with tables, equations, graphs, and other mathematical representations, and objectively and precisely interpret such depictions.
	External Structure	The factor theorem, and integration and derivation of the function relate it to polynomial functions of different power order. In science, this results in certain transformations or in new concepts describing certain rates of change or explaining conservation or change of states.	

Figure 4b: Sample benchmarks associated with the quadratic function (or other power functions) in mathematics.

System: Greenhouse Model/ Effect (GHE)		Episleme	Sample habits
Scope	**Domain**	Local and planetary atmospheres where warming takes place by natural or human causes.	Descriptive analysis of the atmosphere and of heat concentration and waves.
	Function	Description, explanation and prediction of local or universal warming, including global warming.	Logical and critical reasoning by virtue of which particular questions are specified that the Greenhouse Model may answer, to certain limits, about local or global warming. Analytical reasoning to set what the model can specifically describe and explain about warming.
Structure	**Composition**	Terrestrial globe, infrared radiation, gases in the atmosphere resulting from natural phenomena (water vapor, CO_2, methane, nitrous oxide & ozone), and from human activities (chlorofluorocarbons, hydrofluoro-carbons, perfluorocarbons, sulfur hexafluoride or SF_6).	Criterial reasoning to classify and quantify various gases and radiations. Differential analysis by means of which specific (primary) entities (gases in the atmosphere and infrared radiation) and object and state properties are exclusively included in the model, and other (secondary) entities and properties are left out.
	Internal Structure	Laws of "optics" describing how infrared "light" can be confined to the atmosphere, and explaining how changes in the concentrations of gases in the atmosphere can increase the confinement rate and cause GHE.	Criterial reasoning to establish internal and external structure by analogy to greenhouses used for farming purposes. Criterial reasoning, relational reasoning and inferential analysis to quantify various greenhouse processes and statistically analyze their impact on life on Earth. Communication dexterity to take advantage of various mathematical (including statistical) representations in this respect. Relational and logical reasoning to realize the interaction between human life and atmospheric changes, and appreciate the need to make that interaction more constructive.
	External Structure	Effect of galactic phenomena and human activities on the atmosphere, and contribution to GHE (e.g., population growth, farming practices, burning fossil fuels, industrial gases, deforestation). Impact of GHE on life on Earth. Necessary changes in people practices, and human adaptation to climate change.	

Figure 4c: Sample benchmarks associated with the greenhouse model/effect in earth science and geography.

System: Narrative Texts		Episleme	Sample habits
Scope	**Domain**	Fictional or non-fictional account of a meaningful sequence of events that take place in a particular setting and that can be told from different perspectives.	Criterial reasoning and differential analysis to classify various forms of texts.
	Function	Description and explanation of events for information, entertainment or interaction purposes.	Logical and critical reasoning by virtue of which particular questions are specified that narrative texts may answer about certain situations or events.
Structure	**Composition**	Typical elements may include setting, characters, climax, conflict, events, resolution, theme, symbols and point of view.	Differential analysis by means of which specific (primary) entities and properties are exclusively included in the text, and other (secondary) entities and properties are left out.
	Internal Structure	Description of the way different elements interact and evolve in a sequence of events that may, among others, go through exposition, rising action, climax, falling action, and resolution	Criterial reasoning to ascertain, compare, classify, and contrast to the extent that is necessary characters and settings. Relational reasoning to relate characters and settings, and thus specify symbols, characterization and theme. Exploratory and inferential analysis to describe and explain the conflict, and infer a particular ending. Logical reasoning to set particular assumptions, make metaphors and arguments, and come up with viable points of view, judgments and extrapolations. Communication dexterity to express all the above with clarity and readily allow sense making and objective interpretation of text.
	External Structure	Relation to other types and genres of texts.	

Figure 4d: Sample benchmarks associated with narrative texts in English language.

Figure 4: Sample systems outlined in the form of epistemic and cognitive benchmarks.

As such, conceptual systems: (a) ensure a cohesive structure of expert episteme and paradigm, and constitute the most accessible, efficient and reliable building blocks in knowledge construction and deployment, from an expert perspective, and (b) they serve as most fundamental pedagogical tools for students to develop their profiles in commensurability with expert profiles. PSE thus calls for the development of any course in a middle-out approach whereby: (a) all target conceptions (concepts, laws, or any other theoretical entity or statement) at any level are supposed to be developed as building blocks of corresponding systems, and not as self-contained entities, and (b) all target processes or habits (skills, dexterities or dispositions) are meant to be developed for the purpose of constructing and deploying systems.

The middle-out, system-based approach in PSE allows students to realize a coherent big picture of various course materials within a given field and, most importantly, across various fields. The 4-P profile is promoted in PSE in cross-disciplinary curricula in order to help students destroy the compartmental barriers within individual disciplines or fields and, especially, between various disciplines, and transcend the piecemeal approach within and across various fields. Cross-disciplinarity in PSE involves meaningful and productive development of: (a) cross-cutting or common conceptions, structural design, and processes or habits, as well as (b) of the capacity to bring together field-specific aspects to deal with particular abstract or concrete everyday life situations. Such development is best realized, according to PSE, when students are explicitly engaged in the construction and deployment of conceptual systems that best reflect the paradigmatic nature of various fields, and that empower students to readily transfer whatever they learn in one field to other fields.

5. Critical thresholds

Various conceptual systems within the scope of any course 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 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” (Figure 5). The basic threshold separates *core* systems from *fundamental* systems (and related habits), while the mastery threshold separates the latter from *emergent* systems.

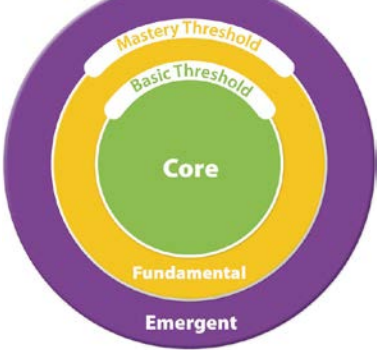

Figure 5: Critical thresholds in a given course.

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 of the field which the course 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. Emergent systems may emerge from the composition of two or more core or fundamental systems, or may be entirely new and more complex systems.

A student needs to meaningfully develop core systems *entirely* 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 assistance in order to reach such threshold, especially at the epistemic level. Once students cross it, 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 one particular system in another course. In the latter case, core, fundamental and emergent parts of the course may pertain to subsidiary systems or to conceptions of increasing complexity and habits necessary for their development. Subsidiary systems are particular instances of the target system that students may be familiar with, and that may facilitate the development of that system.

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. 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 and evolve towards the mastery threshold and beyond.

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 concepts and laws 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).

6. Taxonomy of learning outcomes

Under PSE, the 4-P profile (Figure 3) is translated in any given curriculum in the form of epistemic, cognitive, behavioral and metacognitive learning outcomes in accordance with a taxonomy developed by this author. The taxonomy may be applied under any pedagogical framework to specify conceptions, reasoning skills, dexterities and dispositions that students need to achieve in any educational field for success in modern life.

Taxonomy is the main interface between the framework of a curriculum and its practical aspects, namely the program of study of the corresponding field(s) at each grade level, and the means and methods of learning, instruction and assessment. The main goal of any curriculum, as we see it, is to help students develop a particular profile by the end of schooling years). While PSE works to empower students with the 4-P profile (Figure 6), other pedagogical frameworks define the target profile under different names, and in different ways. Ideally, the profile is practically translated into “expectations”, or reifiable outputs of one form or another which students are expected to achieve in certain respects and to certain extents by the end of each grade or educational level (e.g., outcomes, benchmarks, competencies, or objectives). Under PSE, the 4-P profile is preferably translated into “learning outcomes” which students are expected to gradually develop within and across grades.

Taxonomy, in general, is a generic tool that classifies expected outputs of any sort (learning outcomes or other) in a way that facilitates the deployment of a curriculum in all respects, from textbook authoring, to lesson planning and execution, to assessment. The classification is artificial, in the sense that profile constituents like conceptions and reasoning skills are not anatomically distinguished as such in our brain, and a variety of such constituents is always invoked simultaneously in our mind, in any mental or physical activity (although one constituent may dominate others). However, it is necessary to properly organize expectations in education and monitor how well they are individually achieved. That’s what taxonomy is for.

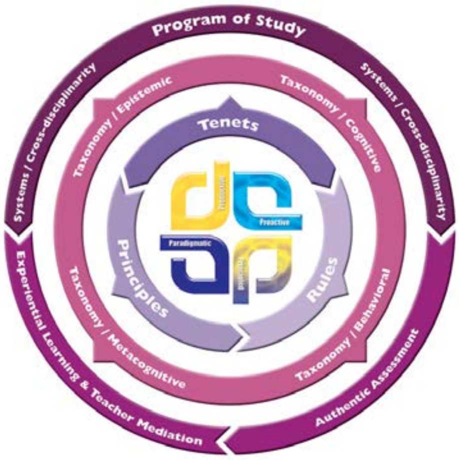

Figure 6: PSE deployment for the development of the 4-P profile.

Our taxonomy is four-dimensional: epistemic, cognitive, behavioral and metacognitive. The *epistemic* dimension helps spelling out everything students need to “know” about various *conceptions* in any educational field. Conceptions include concepts, laws, principles, theorems, and any other statement accepted by a given community of professionals (the entire repertoire of which makes up the “episteme” of that community). The *cognitive* dimension helps identifying the *reasoning skills* required for meaningful understanding and productive deployment of these conceptions, individually or together in specific models or systems. The *behavioral* dimension helps specifying the *dexterities*, or practical skills (or competencies for some), required for the same purpose. The *metacognitive* dimension helps indicating the *dispositions* needed to control student engagement in the other three dimensions for efficient and meaningful profile development and deployment.

Table 1
The PSE Taxonomy

Dimensions / Facets	**Epistemic**	**Cognitive**	**Behavioral**	**Metacognitive**
	Domain	Analytical reasoning	Communication dexterities	Affects
	Function	Criterial reasoning	ICT dexterities	Attitudes
	Composition	Relational reasoning	Manipulative dexterities	Morals & ethics
	Internal structure	Critical reasoning	Artistic dexterities	Values
	External structure	Logical reasoning	Eco-engagement dexterities	Views & beliefs

Each of the four dimensions in our taxonomy consists of five facets (Table 1). The epistemic dimension covers the content knowledge pertaining to the scope and structure of any system or related conception, and more specifically its domain and function (scope), along with its composition, internal structure and external structure (structure). Each facet of the other three dimensions includes a variety of reasoning skills (cognitive dimension), dexterities (behavioral dimension), or dispositions (metacognitive dimension). The four taxonomy dimensions and the way their facets are translated into learning outcomes are outlined in a companion paper (Halloun, 2012).

7. Cognitive development and profile evolution

There is no particular cognitive hierarchy among the four dimensions of the taxonomy or among the five facets in any dimension. However, a certain hierarchy may be identified within each facet that depends on the complexity of, and cognitive demands imposed by, each facet or expectation within.

For example, within the cognitive facet of analytical reasoning, we may distinguish between exploration and differentiation, or between description, explanation and prediction. Exploration is about the comprehensive survey of particular situation (system or phenomenon), without distinction between various elements in that situation. Differentiation, however, is about distinguishing between primary and secondary factors, i.e., and respectively, between factors that are pertinent to the situation and those that are not. Description and explanation are respectively about how and why the situation exists as it does at a given point of space and time, while prediction is about how the situation 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 comes at a higher cognitive level than exploration, and that prediction comes at a higher level than explanation (identifying primary causes of a given situation) followed by description (identifying primary constituents of the situation).

According to PSE, the profile of a person evolves in four consecutive stages across various grade levels. Those stages are best understood in the context of particular systems in a given educational field, as detailed along the four dimensions of the taxonomy. Accordingly, any person may progressively develop all sorts of outcomes about a given system in the following four stages:

1. *Initiation* (*primitive learning*), when a learner is simply aware that the system exists, but knows nothing or a little about its scope and structure, and is still incapable of successfully developing or deploying necessary conceptions, reasoning skills, dexterities and dispositions in any situation.

2. *Gestation* (*rote learning*), when the learner develops partial knowledge about the scope and structure of the system, and is capable of deploying certain conceptions, reasoning skills, dexterities and dispositions, exclusively in the context of the system in question when encountered in familiar situations.

3. *Replication* (*reproductive learning*), when the learner develops satisfactory knowledge about the scope and structure of the system, and is capable of deploying conceptions, reasoning skills, dexterities and dispositions, exclusively in the context of the system in question, when encountered in familiar situations and new, but mostly similar, situations.

4. *Innovation* (*productive learning*), when the learner develops comprehensive knowledge about the system, and is capable of creatively deploying corresponding conceptions,

reasoning skills, dexterities and dispositions, within the context of the same and other systems encountered in totally novel and unfamiliar situations.

In relation to the thresholds of Figure 5, the basic threshold somewhat corresponds to the third stage of replication, whereas the mastery threshold corresponds to the fourth stage of innovation.

Table 2 shows the terms used in PSE to indicate the level at which students are expected to develop each facet at a given stage of profile development. A student may be at different stages in the four dimensions of the taxonomy, or even relative to the five facets within the same dimension. However, a given profile stage necessitates that the student reaches exactly the same stage in all four dimensions of the taxonomy.

Table 2
PSE Developmental Stages

Stage	Profile	Conception	Reasoning	Dexterity	Disposition
1	Initiation	Encounter	Inception	Observation	Awareness
2	Gestation	Recognition	Attempt	Approximation	Adaptation
3	Replication	Comprehension	Reproduction	Performance	Compliance
4	Innovation	Understanding	Production	Perfection	Commitment

8. Mediated experiential learning cycles

Under PSE, students are constantly engaged in a variety of experiential, i.e., hands-on, minds-on learning activities that help them develop expert episteme meaningfully, and expert habits productively (Figure 6). All activities are conducted within well-structured, 4-phase learning cycles (exploration, adduction, formulation, deployment), each cycle being devoted primarily for the construction of a particular conceptual system.

A PSE learning cycle is a cycle for system construction and deployment. Each cycle begins with an *exploration* phase whereby students discover the potentials and limitations of conceptual systems (or specific related conceptions) they have developed so far, and realize the need to construct a new system. Students are then directed, in the *adduction* phase, to propose a candidate system and an appropriate strategy for testing the validity of that system. The strategy, subsequently implemented in the *formulation* phase, would take students into a process of gradual corroboration and progressive refinement of the proposed system. At certain points during the process and afterwards (*deployment* phase), students deploy the system in order to consolidate it and relate it to other systems within the context of the paradigm which all these systems belong to. The PSE learning cycle is described in a companion paper (Halloun, 2004/6).

Throughout a given cycle, students are guided to gradually develop a given system along the four dimensions of the taxonomy and following the four stages outlined in Section 7 above. The conceptual system may relate to abstract and/or concrete situations, and it may involve conceptual entities that may or may not represent physical entities. In this respect, scientific conceptual systems do necessarily represent patterns in the physical world, whereas some mathematical or linguistic systems may pertain exclusively to abstract entities. In either case, PSE learning cycles are experiential.

PSE learning cycles are experiential in the sense described in Dewey's "transaction" and Lakoff's "experientialism". They are student-centered in the sense that they engage students actively and explicitly in negotiations between their own paradigms and the target expert paradigm, so that individual students' profiles evolve consciously and systematically in commensurability with the expected profile. To this end, the process is teacher-mediated in the sense that it does not leave students out entirely on their own free will. Any course has a specific agenda to fulfill: meaningful and insightful evolution toward the target 4-P profile. This agenda cannot be fulfilled without teacher mediation that prevents students from going astray and wandering in futile paths, and that structures their experiential learning activities for the gradual development of the target profile.

Teacher mediation is meant to constantly induce students to reflect back on whatever episteme or habit that they might already possess, and that relate to what they are learning in the classroom. Such reflection is made *insightful* in the sense that individual students become consciously aware of the limitations of their own conceptions and habits (including their learning styles), and of the sources of error when committed, and they explicitly realize what makes expert paradigms superior from all perspectives. The reflection is also *regulatory* in the sense that individual students resolve any incommensurability between their own paradigms and expert paradigms, and they progressively proceed in the direction of achieving the 4-P profile.

Rules of engagement in the learning process may somewhat recapitulate the historic development of expert paradigms. Educational research has systematically shown in the last three decades that students are encumbered with naïve paradigms that are often reminiscent of those known in the historical development of human thought. Teachers are subsequently encouraged to turn to the history of each field in order to better understand the foundations of student paradigms and identify historical cases that may be deployed in educational settings for regulating students' knowledge and resolving incommensurability between student paradigms and expert paradigms.

In science, for example, student regulation may be directed in ways that recapitulate the history of science, especially at critical turning points whereby Galileo and his successors relied on systematic modeling of physical patterns to overcome the limitations of naïve thinking and take science into major paradigmatic shifts. In fact, under PSE science instruction, student realism is often successfully regulated to reach certain level of commensurability with scientific realism, by guiding students through processes similar to those of successive refinements of model-laden theory and inquiry which Galileo and his successors went through.

9. Authentic assessment

Teacher mediation in PSE is guided by authentic assessment which allows teacher and students to reliably: (a) ascertain the extent to which individual students meaningfully achieve all sorts of learning outcomes at specific points of instruction, (b) identify progress or evolution paths of individual students' profiles throughout the course of instruction, (c) track and efficiently regulate the evolution of student profile along these paths in meaningful ways, and (d) evaluate and efficiently regulate course content and teacher practice, and subsequently the curriculum.

Assessment in PSE is not an end by itself. It is meant to be authentic assessment "*for*" meaningful learning and not assessment "*of*" rote learning of course materials. PSE assessments are thus designed to guide learning and instruction (Figure 6). To this end, assessment items of any type or form are designed, and student performance marked, so as to indicate to what extent the student has developed a given conception, reasoning skill, dexterity or disposition.

Under PSE, teachers rely on the profiling rubric of Table 3 for designing various types and forms of assessment tools, as much as they rely on it for planning and carrying out instruction. The rubric reflects the 4-stage profile evolution discussed in Section 7 to guide the process of accumulating “scores” on various items pertaining to a given dimension in the taxonomy, and to indicate the level at which the profile of a given student has evolved along that dimension. Tracking and regulating the evolution of individual students’ profiles being the major objective of assessment, teachers design and deploy their tools in order to determine the stage reached by a given student in the 4-stage hierarchy, and subsequently prescribe the appropriate remedial or reinforcement learning activities. In the process, teachers pay special attention to the critical thresholds discussed in Section 5.

Table 3
Profiling Rubric

Level	Epistemic	Cognitive / Behavioral / Metacognitive
1	The student has ***barely*** realized, if any, the scope or structure of a system.	The student ***barely*** demonstrates her/his ability to deploy the habit (reasoning skill, dexterity or disposition) in the context of any system.
2	The student has ***partially*** realized the scope and structure of a system as demonstrated in ***familiar*** situations.	The student demonstrates her/his ability to ***partially*** deploy the habit in the context of certain ***familiar*** systems/ situations.
3	The student has realized the scope and structure of a system, ***to the extent that is required***, as demonstrated in ***familiar*** situations or similar new situations.	The student demonstrates her/his ability to deploy the habit, ***to the extent that is required***, in the context of ***familiar*** systems/situations or similar ones.
4	The student has reinforced her/his knowledge about the scope and structure of a system ***beyond what is required***, as demonstrated in new situations that are ***not similar*** to familiar ones.	The student demonstrates her/his ability to deploy the habit ***beyond what is required***, in the context of new systems/situations that are ***not similar*** to familiar ones.

10. PSE deployment

PSE is deployed in a number of projects at Educational Research Center (ERC), including two major pan-Arab initiatives, the International Arab Baccalaureate (IAB), and a teacher education program that will soon be launched for continuous professional development of in-service teachers. IAB is a school-based program that promotes the development of the 4-P profile (Figure 6). It relies on an electronic platform for authentic assessment that allows continuous monitoring of individual students’ profiles and of various authentic assessment items accessible through the platform. The platform is gradually evolving into an e-learning platform that would be used for blended learning in both IAB and the teacher education program. Ample details about these and other PSE initiatives are beyond the scope of this paper, and can be found at *www.EducationalRC.org*.