## Systemic Cognition and Education

# Taxonomy of Learning Outcomes: Rational Subsets

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SCE taxonomy of learning outcomes is a four-dimensional, multifaceted taxonomy. It covers epistemic, rational, sensory-motor, and axio-affective learning outcomes. Each dimension is broken down into a number of facets, and each facet is divided into a number of subsets. This document presents five tables offering subsets or particular reasoning skills of the five rational facets in the SCE taxonomy: analytical reasoning, criterial reasoning, relational reasoning, critical reasoning, and logical reasoning[1].

Each subset or particular reasoning skill is described in the respective table, and illustrated with a sample learning outcome pertaining to the Earth system within a Sun-Moon environment (E/SM). The system is delineated and the sample learning outcomes stipulated to serve the function of describing, explaining, or predicting three particular terrestrial phenomena: the day and night cycle, seasons, and sea and ocean tides[1].

The reader is invited to keep the following points in mind while examining the five tables, and subsequently when using them in curriculum development and deployment, from lesson planning and implementation to student assessment and curriculum evaluation:

1. The list of subsets or skills, like that of facets, is neither exclusive nor exhaustive. It simply includes, for illustration purposes, reasoning skills that may be most commonly targeted in teaching and learning any field or subject, and that subsequently make up a reasonable checklist for planning and evaluating instruction and assessment.
2. Two major issues distinguish subsets from each other. First, each subset is about a particular reasoning skill that serves a distinctive function in our minds and that brings about outcomes that no other reasoning skill can bring about. Second, development and deployment of various learning outcomes pertaining to any subset are supposed to impose cognitive demands of almost the same level.
3. Each subset or skill is given a particular name or label and outlined under "Reasoning skill description". A given label may colloquially indicate different things to different people. However, for coherence and uniformity purposes, it is advised that the shown labels be used under SCE as indicated in the tables below, with a reasonable leeway for contextual interpretation and extrapolation.
4. “Sample learning outcomes” in the last column of each table below are provided for illustration purposes in the context of the E/SM system (Fig. 1). As stated, each outcome is a broad expectation of student achievement that cannot be assessed in a single exam item. Each statement often needs to be broken down into a number of narrower statements to become suitable for writing exam items.

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[1] Halloun, I. (2017/19). *SCE Taxonomy of Learning Outcomes*. Jounieh, LB: H Institute.

5. In general, no specific "action verbs" are recommended for stating learning outcomes expected with each subset or reasoning skill. The same verb may be used with different reasoning skills (e.g., to determine, to tell, to figure out). The context of the verb in the learning outcome statement should help the reader specify what a particular reasoning skill is about. Alternatively, different verbs may be used with the same reasoning skill (e.g., to differentiate, to distinguish and to choose used with differentiation). However, certain verbs can be used exclusively with certain skills (e.g., to "describe" used only for the description of "how" things are or behave, and to "explain" used only for the explanation of "why" things are or behave one way or another).
6. Like in any educational taxonomy, the distinction among facets and subsets is artificial in at least two respects. First, no reasoning skill, and thus no facet, occupies alone an exclusive, or a privileged area in the brain. Various reasoning facets and subsets share the same brain lobes, and involve common neural networks. Second, any cognitive or behavioral activity, no matter how simple it might be, involves many dimensions of the SCE taxonomy -- and often all four, epistemic, rational, sensory-motor, and axio-affective dimensions --, and many facets within the same dimension.
7. Any human activity, and thus any educational activity, involves, as stated above, many dimensions and many facets of the SCE taxonomy. Certain activities though may be more involved than others. This is especially the case with activities like planning (an experiment, for example), decision making (e.g., in group work), and all sorts of problem solving, which are complex activities, especially from rational perspective. Any activity of the sort involves so many reasoning skills that, at least under SCE, it cannot be classified as a single "reasoning skill" (or any other form of categories, competencies included).
8. Any assessment item, like any educational activity, involves many dimensions and many facets, and thus many reasoning skills of the SCE taxonomy. However, each assessment item, especially items included in typical tests and exams, is written under SCE so as there is always a *dominant* dimension and a dominant facet in any activity, i.e., a facet that is more involved than all other facets and that affects the most the outcome of the activity. For example, when the dominant facet is rational, there is always one *dominant reasoning skill* among all reasoning skills required by the item. That dominant reasoning skill makes up the subject of the learning outcome ascertained by any single item.
9. The demarcation line between two rational facets, and between two subsets in any given facet, may sometimes be blurred and hard to define sharply. Unique assertions are made in the SCE taxonomy in order to relatively diffuse this intricacy. For example, in order to sharpen the distinction between analytical reasoning and other types of reasoning, analytical reasoning skills are considered dominant more in the deployment of already acquired conceptual knowledge (e.g., laws and rules) than in the generation of new knowledge. In the latter event, other facets, especially critical reasoning and logical reasoning become dominant. To illustrate this point, consider the sample learning outcomes provided in the table below for differentiation (analytical reasoning) and critical choice (critical reasoning). Differentiation is considered to be, say, the ability of the student to "ignore the distance between the Earth and the Sun and concentrate on the angle of incidence of sunlight when studying seasons on given spots on Earth". In contrast, critical choice is about the student ability "to figure out, by comparing seasons in the two hemispheres at a given time of the year, that the tilt of the Earth's axis of rotation and not its distance from the Sun is behind the occurrence of seasons". As such, under critical choice, the student is supposed to come, on her/his own, to the proper judgment regarding the features in question, whereas under differentiation s/he is assumed to deploy what s/he *has already figured out* about these features to study seasons at specific spots on Earth.

10. Every effort should be deployed under SCE to cover, in every course, all facets of the SCE rational dimension with all subsets or reasoning skills identified in this document (and more). The level and scope, and even the possibility, of coverage of every reasoning skill may vary from course to course or from one system to another within a given course. However, an overall balance needs to be maintained between all five rational facets, especially in various forms of assessments.
11. Reasoning skills cannot be sufficiently measured on paper. Paper exams, or typical online exams, can only provide a rough assessment of reasoning skills. Fair assessment of any reasoning skill requires long-term monitoring of students in action in open discussions. As discussed in a separate document, cross-disciplinary projects are meant to serve this purpose.

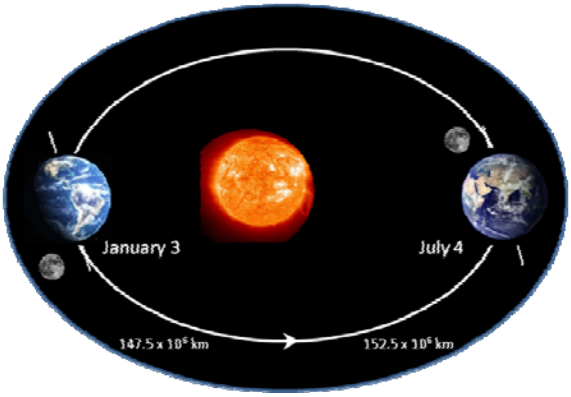


**Figure 1**. Graphic depiction of the Earth / Sun-Moon system (E/SM) [1].

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

| Facet | Subset | Reasoning skill description | **Sample learning outcome**<br>Earth system within a Sun-Moon environment (E/SM) |
|---|---|---|---|
| **Analytical reasoning** | Survey | Observing/exploring a new situation* and identifying all observable features (entities, processes, and their properties) without distinction. | The student is able to list the celestial bodies that make up the E/SM system, identify their apparent behavior, and detail their properties (e.g. mass, size, trajectory, period). |
| | Differentiation | Distinguishing between primary and secondary features, i.e., between features that significantly affect a given situation (primary or relevant) and those that do not (secondary or irrelevant). | The student is able to ignore the distance between the Earth and the Sun and concentrate on the angle of incidence of sunlight when studying seasons on given spots on Earth. |
| | Regularities' specification | Identifying regularities or recurrent features in the given situation (that may or may not reflect a universal *pattern*). | The student is able to recognize the recurrence, year after year, of sunrise and sunset at specific times in a given day of the year. |
| | Description | Specifying primary features and corresponding descriptors (parameters and/or variables) that reliably and sufficiently depict "how" the situation happens to be. | The student is able to describe with appropriate parameters the rotation of the Earth around itself and its translational orbit around the Sun. |
| | Explanation | Stipulating "why" the situation happens to be as described, by identifying the causes (if any) behind its state and primary features. | The student is able to attribute the Earth's orbit around the sun to the mutual gravitational pull with the Sun. |
| | Prediction/ Post-diction | Anticipating how the situation will evolve under specific conditions, or telling how it has actually evolved in the past to get to its current state. | The student is able to predict the consequences on seasons of future variation in the tilt angle of the Earth's axis of rotation. |

* A "situation" may involve one or many systems (or parts of systems) in specific states or undergoing certain processes. It may be abstract (e.g. literary or scientific text) or physical (e.g., the E/SM system of Figure 1). Reasoning skills may pertain to semantic aspects (meaning and significance) or syntactic aspects (connections, system structure, state or change of state) of the situation.

| Facet | Subset | Reasoning skill description | Sample learning outcome<br>Earth system within a Sun-Moon environment (E/SM) |
|---|---|---|---|
| Criterial reasoning | Setting criteria | Specifying standards, norms, benchmarks, scales, and other types of criteria that govern all rational processes in this facet. | The student is able to set the criteria for classifying planets and satellites. |
| | Classification | Grouping features into well-defined categories, based on analogies or common criteria. | The student is able to classify countries with similar climate based on their latitudes. |
| | Comparison | Specifying whether two or more entities or processes in a given situation are alike or different in terms of a given property (ies). Depending on how a property can be measured, the comparison may be nominal, ordinal (contrast included), interval-type, or ratio-type. | The student is able to tell that the seasons on Earth and Moon are different based on the difference in composition and atmosphere. |
| | Measurement | Comparing a given feature in the situation to a standard scale or unit, if applicable. | The student is able to provide the diameter of Earth in km or miles. |
| | Estimation | Assigning approximate values (or ranges of values) to a given feature in the situation. | The student is able to estimate the range of change in temperature between day and night on a given spot on Earth, during a given season. |
| | Analogical mapping | Establishing analogy between two parts of a situation (or two situations) by correspondence to common features (criteria), or setting the features of a given part (or situation) by analogy to another similar part (or situation). | The student is able to tell that another country that has the same climate and similar water resources as her/his own country may have the same types of vegetation. |

| Facet | Subset | Reasoning skill description | Sample learning outcome<br>Earth system within a Sun-Moon environment (E/SM) |
|---|---|---|---|
| Relational reasoning | Systemic organization | Organizing a given situation in the form of systems or other coherent structures. | The student is able to organize information provided about the E/SM system in a given text according to the SCE system schema and/or related epistemic structures. |
| | Semantic connections | Relating features in a given situation according to their meanings or significance, directly or through contextual relationships. | The student is able to build a concept map or a semantic network about the E/SM system. |
| | Syntactic connections | Relating features in a given situation, according to structural or functional aspects, in the form of laws, rules, or any other type of relationship (mathematical included). | The student is able to relate the gravitational interaction between the Earth and the Sun to the mass of the two bodies and the distance that separates them using Newton's law of universal gravitation. |
| | Synthesis | Painting the big picture in a given situation, and/or relating that situation to other situations in a generic, broad context (e.g. scientific theory or genre of texts). | The student is able to situate or integrate knowledge about the E/SM system in knowledge about the Solar system or the Milky Way galaxy. |
| | Extrapolation | Expanding the merits of the situation at hand to serve new domains and functions in the corresponding field of study. | The student is able to use what s/he has learned about the occurrence of darkness at night to determine how it gets dark on Earth during eclipses. |
| | Transfer | Exploiting what is learned in a given situation or field in different fields according to clear rules of correspondence (bridging analogies included), thus investing the merits of the situation in cross-disciplinary contexts. | The student is able to transfer what s/he learns about gravitational interaction in the E/SM system to the electrostatic interaction in Bohr's model of the atom. |

| Facet | Subset | Reasoning skill description | Sample learning outcome<br>Earth system within a Sun-Moon environment (E/SM) |
|---|---|---|---|
| Critical reasoning | Question and problem formulation | Generation of a valid question(s) and/or a proper problem statement(s) about a given situation. | The student is able to ask the proper questions about the changes of season on Earth (e.g., the causes and impact of heat variation). |
| | Purposeful information gathering | Deciding what information needs to be gathered about a particular situation in order to ascertain a hypothesis, answer a question, or solve a problem about that situation. | The student is able to collect proper temperature and precipitation records at specific times of the year in order to determine how seasons vary across the globe. |
| | Critical choice | Ascertaining various features in a given situation, and determining, based on evidence and/or proper argumentation, which are primary features and which are secondary features. | The student is able to figure out, by comparing seasons in the two hemispheres at a given time of the year, that the tilt of the Earth's axis of rotation and not its distance from the Sun is behind the occurrence of seasons. |
| | Evaluation | Ascertaining the viability (validity, reliability, etc.) of all sorts of assertions (claims, arguments, supposed facts or evidence, etc.) presented in support of, or against, a given idea or hypothesis. | The student is able to ascertain, and subsequently refute, the hypothesis that the moon rotates around itself once a day. |
| | Reflective thinking | Evaluation *and* regulation of one's own ideas (especially misconceptions) or others' ideas about a given situation. | The student is able to ascertain her/his own ideas about seasons, internally through coherence assessment, and externally by comparison to peers' ideas. |
| | Challenge anticipation | Anticipating, and accounting for, conceptual, rational, and/or practical demands that may be imposed by certain possible changes in a given situation. | The student is able to anticipate the rise of tides in a given area under severe climate change (e.g., in the case of hurricanes). |

| Facet | Subset | Reasoning skill description | Sample learning outcome<br>Earth system within a Sun-Moon environment (E/SM) |
|---|---|---|---|
| Logical reasoning | Pattern recognition | Recognizing aspects of a given situation that figure in other situations, and that are universal in space and time (cultures included). | The student is able to recognize that there are billions of celestial systems in the universe that are governed by the same state and interaction laws as the E/SM system. |
| | Making assumptions | Making assertions about missing features or incomplete or superfluous data in a given situation in order to make it meaningful. | The student is able to assume that the difference in climate between two countries on the same latitude is due not to external but to internal, geographic factors. |
| | Conjecturing / Hypothesis formulation | Proposition of tentative, plausible answers to questions or solutions to problems pertaining to a given situation, whether abstract (conjectures) or empirical (hypotheses). | The student is able to propose a hypothesis regarding the variation in climate across the globe, or the change in climate across the years in a given part of the globe (e.g., greenhouse effect). |
| | Proof / Corroboration | Providing abstract argumentation (mathematical included) to support or refute a conjecture (proof), or empirical evidence to support or refute a hypothesis (corroboration). | The student is able to come, after data analysis, to properly accept or reject the hypothesis made regarding climate variation or change. |
| | Justification | Supporting, with proper arguments, a decision or the solution proposed to a given problem. | The student is able to properly justify the decision made about the moderation of climate change. |
| | Inferences | Coming to a conclusion about a given situation(s) through adduction, induction, deduction or generalization (cf. below for details*). | The student is able to deduce that factors that cause climate change in a given part of the globe may affect the entire globe. |
| | Metaphoric assertion | Making abstract statements, or proposing solutions to conceptual / abstract situations, by reference or simile to physical situations, or vice versa. | The student is able to write a narrative text about a human or cultural situation by drawing on specific aspects of the E/SM system (e.g., change of mood described in terms of change of seasons). |

* Induction: The inference of a law, theorem, or any other general statement from limited observations / situations.

Deduction: The inference from a law, theorem, or any other general premise of an assertion regarding a particular situation.

Adduction: The inference from several separate (familiar) situations of an assertion regarding a particular (new) situation, including the case of bringing in a given conceptual model(s) to solve a problem pertaining to a physical situation.