Learning objectives for system dynamics competency

What

Goal: to improve the teachability and standardization of system dynamics and thereby foster its wider adoption at education institutions.

Who

Martin Schaffernicht
Universidad de Talca
martin@utalca.cl

Stefan Groesser
Bern University of Applied Sciences
stefan.groesser@bfh.ch

SD competency

What should one know, understand and to be able to do well at the end of different levels of training in system dynamics?

Beginner (e.g., K-12 level courses) → Advanced beginner (e.g., undergraduate) → Competent (e.g., graduate/master) → Practitioner Ph.D. → Expert

On-line Delphi process

Experts

We

Phase 1: establish learning objectives

Define initial set of learning objectives → Classify, correct and amend → Analyze & synthesize → Comprehensive schema of learning objectives

Phase 2: establish competency levels

Indicate inclusion of learning objectives for: beginner, advanced beginner, competent, practitioner, expert → Classify, correct and amend → Analyze & synthesize → Learning objectives for each competence level

Bloom's taxonomy

Complexity: Hi ↑ Lo

Validating the simulation model

Combines Creating and Evaluating: testing, measuring, judging and modifying.

Tests model's structural validity: *Tests*, *validates* and *corrects* dimensional consistency. *Tests* and *validates* each variable's correspondence to a real entity. *Corrects* errors in variables' correspondence to a real entity. *Judges* a model's membership of a model family.
Tests models' behavioral validity: *Measures* and *validates* the historic fit . *Tests* and *validates* extreme condition behavior. *Tests* and *validates* the sensitivity of the model with respect to uncertain parameters.

Creating models

Putting elements together to form a coherent or functional whole: generalize, modify, design, hypothesize and develop.

Develops hypotheses in the context of a problem (based upon a S&F model). *Hypothesizes* plausible behaviors of variables in generic formulations. *Designs* a qualitative model (CLD or S&F) : *Uses* key agents' mental models. Starts from key accumulations. *Infers* key variables. *Connects* variables to reference modes. Assures endogenous orientation. Takes care of the measurement of variables. *Documents* the modeling process
Designs a quantitative S&F model (quantifies the variables): Starts with simple fragments of structure. Takes care of validity during the modeling process. Simulates after adding one piece of structure. *Distinguishes* the perceived from the actual conditions
Modifies: the S&F model to achieve validity (Validates the S&F model), the model to test scenarios or candidate policies (Exploits the S&F model). Improves the situation. Knows when to stop the modeling process.

Evaluating possible modeling projects

Making judgments based on criteria and standards: *decide*, *test*, *measure*, *judge* and *explain*.

Prepares a modeling project: *Establishes*: the clients of a project, the symptoms that give rise to the project, the reference modes, if system dynamics is an appropriate methodology.
Establishes a problem (with logical and temporal scope): *Establishes* desirable and feared futures, the time horizon, a conceptual boundary. *Engages* clients and other relevant actors. *Formulates* a conceptual model (dynamic hypothesis)
Establishes the purpose of the modeling project

Evaluating policies and problems

Explains: the causal structure of a problem or situation, how the problem is created by this structure, why one policy has high impact while others fail to do so, how established policies are the underlying cause of the problematic behavior. *Argues* in favor of better policies.

Analyzing models

Breaking material into constituent parts, determining how the parts relate to one another and to an overall structure: *explain*, *compare*, *explain*, *infer*, *classify* and *analyze*.

Infers feedback loops in CLDs and SFDs. *Classifies* the loops' polarities. *Analyzes* CLDs (structure and possible behavior): *Interprets* the CLD structure. *Infers* plausible behavior patters. *Decides* when simulation is required.
Explains CLDs (structure and possible behavior). *Analyzes* S&F models: *Infers*: a stock's accumulation behavior given the flows, a flow's behavior given the stock's accumulation behavior. *Interprets* the S&F structure using diagram and equations. *Formulates* hypotheses relating parts of the structure to certain behaviors. *Experiments* with simulation models to assess proposed hypotheses.
Explains S&F models (structure and behavior). *Compares* S&F models. *Explains* similarities between S&F models. *Generalizes*: proposes a general S&F model for a concrete situation

Applying the steps of the modeling process

Carrying out or using a procedure: being able to *apply*, *classify*, *experiment*, *discover*, *use*, *resolve*, and *construct*.

Decides: the model boundary. *Discovers*: the time horizon, the variables *implied* by spoken or written text. *Classifies*: the variables by type, the variables' units of measure. *Discovers*: causal links implied by spoken or written text. Classifies: the links' polarities. *Discovers*: delays. *Computes*: flows from data about stock accumulation behavior. *Discovers*: the polarity of the causal relation between two variables, the shape of nonlinear causal relations between two variables. *Applies*: the guidelines of good CLD development (Sterman, ch. 5): Indicates: the polarity of causal links, the polarity of loops. the important delays in causal links. Names: the loops, the variables as nouns. Designs a CLD's layout in a readable manner. Choses an appropriate level of aggregation. Includes only the important loops. Makes the goals of negative loops explicit. Distinguishes between actual and perceived conditions
Constructs: a CLD based upon a SFD , a SFD based upon a CLD. *Uses* simulation to reproduce historical behavior, to formulate hypotheses. *Experiments* with simulation models to assess proposed hypotheses. *Modifies* simulation models to assess proposed hypotheses, to incorporate policies. *Experiments* with simulation models to evaluate proposed policies. *Resolves* problems using simulation models.

Understanding the concepts of SD

Constructing meaning from oral, written, and graphic messages: *associate*, *interpret*, and *explain*.

Explains: dynamic hypothesis, the types of variables, causality, time horizon, model boundary, polarity, delay, accumulation, flow, policy
Associates: atomic behavior patterns to fundamental feedback structures (exponential behavior to positive feedback, logarithmic behavior to negative feedback), fundamental feedback structures to atomic behavior patterns (positive feedback to exponential, negative feedback to logarithmic and changing loop dominance to transitions in atomic behavior patterns).

Interprets BOT graphs
Describes: a stock's accumulation behavior given the in- and outflows, a flow's behavior given the stock's accumulation behavior

Remembering the concepts of SD

Retrieving, recognizing, and recalling relevant knowledge: being able to *name* things, give *lists*, *definitions* and *examples*

Defines: the purpose of a model, a reference mode, a dynamic hypothesis, the types of variables, causality in terms of polarity, the concept polarity, time horizon, delay, model boundary, causal link, accumulation (stock), flow, units of measure, policy, the difference and the relationship between accumulation and flow, the rules of graphical integration, the rules of graphical differentiation, the method to detect loops, the method for detecting loop polarity
Identifies: the atomic behavior patterns (linear, exponential , the loop structure for overshoot and collapse, delay structures, co-flow and aging chain
Describes: the atomic behavior patterns (Ford: behavioral dominance analysis)

Remembering the system dynamics modeling process

Defines: the objectives of system dynamics, the purpose of each phase in the modeling process, the activities of each phase of the modeling process, the methods applied in each phase of the modeling process, dynamic complexity, the requirements for applying system dynamics
Lists: the phases of the modeling process