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Learning for Sustainability

The Need for a Conversational System Dynamics

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The challenges posed by sustainability generate a pressing need for widespread development of a new learning capacity: the capacity for building *shared*, *systemic* understanding. System Dynamics appears to be a natural for addressing this vitally important learning agenda. But given the pace at which our discipline is being taken up around the world, it would seem that System Dynamics has a slim chance of playing much of a significant role. If we do want to contribute to addressing the challenges to sustainability, we must accelerate the uptake of System Dynamics. I believe that in order to do this, we must create what I will call a "conversational" incarnation of our discipline—something quite different than what has come to be known as "Systems Thinking." This incarnation will preserve what's essential for underwriting rigorous, systemic thinking. And it will excise what serves as the principal impediment to widespread uptake.

The principal aim of this paper is to introduce you to Conversational System Dynamics, and to hopefully get you a little excited about it in the process (though I'd settle even for agitated). I will begin by using the context of sustainability to motivate the need for using an approach like System Dynamics. Space constraints do not permit development of this argument in full detail. I am therefore relying in part on the reader's awareness of the broad variety of System Dynamics applications in the realm of sustainability to bear testament to the relevance of our discipline in this domain. Next, I'll develop an operational definition of Conversational System Dynamics by describing which aspects of "traditional" System Dynamics (what I'll call the "analytical" variety) will be retained in this new incarnation, which will not, and *why*. Finally, I'll describe what would be useful to have in a new software tool if it is to be effective in leveraging widespread assimilation of Conversational System Dynamics.

Sustainability: *Motivating the Need* Sustainability can be operationally defined as the ability to maintain a system's stocks (i.e., its resources) at magnitudes that ensure its ongoing viability. Several formidable challenges arise in seeking to achieve this end. Perhaps the most daunting springs from the widespread absence of a systemic perspective. In the absence of such a perspective, many of the stocks that determine a system's viability are perceived as lying *outside* the spatial and/or temporal boundaries of the system as defined by its residents. As such, these accumulations are either ignored, or considered to be an "issue" for the residents of some *other* system, or some later time.

In reality, many "perceived-to-be-outside-the-boundary" accumulations are impacted by actions taken within locally-defined spatial and temporal boundaries. And, many of these "outside" accumulations do indeed feed back to impact actions generated within locally-defined boundaries! As an example, consider the stocks of anger that built up within the two teenagers who ultimately unleashed violent actions that dramatically fed back to influence conditions within the Columbine High School community—a community from which they were considered to be "on the outside." The stocks of anger were fed by flows generated, at least in part, by classmates who either were oblivious to the associated magnitudes and/or who considered them not to be "their issue."

Because locally-bounded perspectives are more the rule than the exception, there is little sense of joint ownership of "outside the boundary" stock magnitudes, and hence no shared picture of what constitutes a sustainable magnitude for these stocks. And even if such a picture did exist, there is no *shared understanding* of how to maintain the magnitudes of the stocks at levels that will ensure sustainability. The result: *Serious threats to viability*! For evidence, one need look no further than the myriad threats to the sustainability of our global ecosystem posed by over-population, ozone depletion, global warming, de-forestation, and rapidly vanishing supplies fresh water and clean air. But threats to sustainability are not limited to the environmental domain. We've watched .com IPO's meteorically surge to what we know are non-sustainable heights. The growing disparities between haves and have-nots are approaching non-sustainable proportions in many countries around the globe. And, I've already alluded to one example of the levels of anger that too often prevail in our schools (not to mention our workplaces), and which loom as timebomb threats to the viability of these institutions.

If we look for the structural commonality underlying all of these non-viability dynamics, it is that the magnitudes of some key stocks in each system have reached non-sustainable levels. Be it population, ozone, greed, or anger, the stocks have become either too full or too depleted. And, as a result, the viability of the associated system is threatened. But until a widespread broadening of peoples' perspectives is achieved, few will even "see" these stocks, much less feel they "own" them. And until enough people are equipped with the capacity for building a *shared, systemic understanding*, they will not be able to forge common, effective policies for governing the flows that determine the associated stock magnitudes.

Achieving environmental, economic and social sustainability thus implies a *huge* learning agenda! Peoples' perspectives in both space and time must be broadened, and they must also develop the capacity for building *shared*, *systemic* understanding. Is it then…

System Dynamics to the Rescue? System Dynamics certainly would seem to be an almost ideal vehicle for addressing the daunting learning agenda posed by sustainability. Its backbone is a systems perspective. Its language of stocks and flows can depict sustainability in highly operational terms. Its focus is on policy design. But even with all of this going for it, our discipline still has one big problem. Few people know much about it; even fewer can do it well. System Dynamics has been around for more than 40 years. Yet, after all this time, the discipline has but a pinhead's worth of competent practitioners and few educational institutions openly embrace it. Meanwhile, the world's population now stands at 6 billion, and it's doubling every 25 years!

How come? Because people like to have sex. Sorry, answered the wrong "how come." My hypothesis for why System Dynamics has spread so slowly is derived from lots and lots of experience in teaching system dynamics to lots and lots of different kinds of people… mostly quite smart people (because most people are quite smart). My hypothesis is a simple one: System dynamics is too difficult for most people to master, or even to feel some confidence with, in the time they are willing/able to allocate.

Assuming my conjecture is at least in part correct, what strategies can we pursue for addressing the difficult-to-uptake issue? One would be to embark upon a massive campaign to berate people into allocating more time to learning system dynamics. I'm game, but frankly, I just don't think there are enough of us to pull this off on a sufficiently large scale. The other strategy? *Make System Dynamics easier to learn.* This is really what "Systems Thinking" has been all about. And, encouragingly, it has had some impact. But most people in our field agree that there is not enough rigor in the approach. The shared understanding that results is often too shallow and/or too suspect in terms of the dynamic inferences that are drawn. We need to take another cut at the same strategy.

Having spent more than 20 years pounding my head against "the steepness of the system dynamics learning curve" wall, I believe I have discovered a "cut" that works—then again, perhaps I'm just laboring under the rosy glow that frequently accompanies severe brain trauma. I call the "easier to learn" approach *Conversational System Dynamics* (CSD).

Conversational System Dynamics Conversational System Dynamics was created from Analytical System Dynamics (ASD) by retaining much of what the latter provides for underwriting rigorous, systemic thought, while dropping aspects that add some more rigor but do so at too high a price in terms of impeding uptake. The two incarnations of System Dynamics are usefully seen as positioned within a two-space of rigor (of representation) and reliability (of inferences drawn from simulation results) as depicted in Figure 1.

INSERT FIGURE 1

As the Figure indicates, CSD nearly matches ASD in terms of rigor, as manifest in model structure. However, it falls somewhat short of ASD in terms of the reliability of inferences about dynamics that may be drawn from associated simulations. However, the CSD variety of mental model and associated simulation process stands head and shoulders above either the causal loop diagram-based Systems Thinking (ST), or the in-widespread-use "critical success factors (CSF)," type mental models.

Table 1 summarizes specifically what was retained and what was excised in creating Conversational, from Analytical, System Dynamics. Let's begin with what was excised.

INSERT TABLE 1

Equations, converters, and numbers in general were excised. My conclusion based on lots of teaching experience is that the major "disconnect" for the vast majority of people who are seeking to learn system dynamics comes when these things are introduced—which often occurs together. Even though the algebra being used in many System Dynamics models is very elementary, many people just don't "get" equations—at least not very easily.

I don't think the issue here is that people *can't* do the more analytical aspects of System Dynamics. Rather they sense they will need to think very hard in order to do them. It will take a long time to come up to speed. They don't have the time (or the energy). In my experience, most senior and mid-level managers, as well as a great number of teachers, fit these descriptions. Experiencing these reactions on a broad-scale prompted me to ask: Is there a "package" of system dynamics thinking, language and simulation skills that stops short of equations, numbers, and such, but in rigor-of-thinking goes beyond causal loop diagrams and “canned” archetypes? My answer is an unqualified and resounding, “Yes!” And the “package” is what from “traditional” System Dynamics was retained in creating Conversational System Dynamics. So what’s in the package?

What’s “in” begins with stocks and flows. To me, the biggest problem with Systems Thinking, as it has come to be defined, is that the *wrong* language (i.e., causal loop diagrams) was chosen to underwrite it. As we know, from that famous George Richardson paper on the feuding Hatfields and McCoys, one fundamental problem with causal loop diagrams is that they do not distinguish between stocks and flows. This distinction is absolutely critical to making correct dynamic inferences. That’s why inferences drawn from mental simulations of causal loop diagrams are so unreliable. There’s no way to know which relationships are critical to determining dynamics at what point in time and which aren’t. Actually, in most cases, there’s no way even to know what dynamics will be generated!

Using stocks and flows as language building blocks also helps to infuse discipline into the critically-important model boundary-setting process. Flows come automatically-equipped with clouds. Model-builders must make a conscious decision to continue extending the model boundary by covering up a cloud with a stock. In other words, the default imposed by flows is “stop expanding, here!” Causal loop diagrams provide no such “default” braking on the boundary-setting process. Indeed, any word without at least one arrow pointing into and out of it becomes conspicuous—inviting a link to be added. As a result, too often the process of adding words and arrows to causal loop diagrams spins wildly out of control—verifying the maxim that “everything is connected to everything else,” but leaving people with an extensive mish-mash out of which they must try to distill some meaning.

Stock/flow assemblies also must obey dimensional consistency “laws.” These laws prevent one from, for example, flowing customer satisfaction into revenue. But in causal loop diagrams, and other less rigorous visual languages, there are no “units consistency” requirements. This means it’s fair game to connect anything to anything else—indeed, as noted, not just fair game, but an enticing challenge. The result is too often mental spaghetti, an intensive model boundary so tangled that only its creators can appreciate it!

The stock/flow language also facilitates depiction of “infrastructures,” often called “spinal cords” or “main chains” (i.e., horizontal progressions of stocks linked via conserved flows). Infrastructures provide a picture of “what’s flowing” in a system—a picture, by the way, that’s *independent* of the feedback relationships that govern the rates at which things are flowing! Such infrastructures do not exist in the causal loop language, and their absence critically impairs peoples’ ability to conduct reliable *mental* simulations.

For all of these reasons, the stock/flow language was chosen to be the foundation of Conversational Systems Thinking, a foundation shared by Analytical Systems Thinking. As Table 2 indicates, the attributes of the stock/flow language satisfy all the requirements of a lexicon that is capable of supporting development of *widespread*, *shared*, *systemic* understanding. That is, it’s *simple*, *operational*, *visual*, and *rigorous*.

INSERT TABLE 2

A language must be *simple* if it is to be widely taken up. It must be *operational* in order to be capable of transcending functions, disciplines, cultures, or any of the other frameworks that cause people to draw local, "us and them" boundaries. Being *operational* also means the language elements, when pieced together, "tell the story" of how a system actually works—in the process revealing actual levers for changing performance. The language must be *visual* so that it can serve as a true Esperanto, transcending the cultural nuances and ambiguities that perforce plague the spoken and written word. Being *visual* also greatly facilitates mental simulation, increasing the reliability of the dynamic inferences that are drawn from simulation results. Finally, to be effective in building accurate shared understanding and underwriting reliable mental simulation, a language must be *rigorous*. It must be infused with a discipline that guides people toward accurately portraying the structure of those aspects of reality they are seeking to understand, while also helping people to draw correct dynamic inferences from their mental simulations of these structures. The grammar of stocks and flows is suffused with rigor in the form of requirements for dimensional consistency and conservation laws, both of which impose a strong discipline on the model construction and simulation processes.

In addition to stocks and flows as fundamental language elements, we also need "wires" or connectors. These enable us to make an important structural distinction, and to create an essential, higher-level building block. The important structural distinction is that between stock-generated and flow-generated flows. The essential, higher-level building block is the feedback loop. A few words about each…

An important structural distinction—widely employed, but not explicitly recognized by many System Dynamicists—is that between stock-generated and flow-generated flows. Consider the two stock/flow depictions of the activity of splitting wood and the associated build-up of muscle mass (the example illustrates the real reason why System Dynamicists from New Hampshire are so buffed).

INSERT FIGURE 2

Mental simulation easily reveals why depiction "B" is a better representation of the associated muscle-building process and, by extension, why it is important to distinguish between whether it is a stock, or a coincident flow, that is generating a given activity.

The final component of CSD is feedback loops. Little justification for retaining them should be required. And, the good news is that people have very little difficulty in understanding either the general concept, or in distinguishing between the two types.

These are the components of CSD. CSD works. People "get it," and do so, *quickly*! They also derive substantial value from applying it. It broadens their perspective. It improves the quality of the mental models they construct. It facilitates the development of *shared*, *systemic* understanding. It increases the reliability of the dynamic inferences they draw from the mental simulations they perform. All of this is good.

But is it “good” enough? I can already hear the hue and cry of dyed in the wool, traditional System Dynamicists! “Here we go again, watering down the discipline, ‘dumbing down’ the approach.”

Along the axis of rigor, CSD definitely resides “to the left” of ASD. And along the axis of reliability on dynamic inferences, CSD lies below ASD. I would therefore place more confidence in conclusions drawn from well-constructed, numerically-outfitted, computer-simulated ASD models, than in those drawn from mentally-simulated CSD models. *However*, the reality is, again, that after 40 years of sustained practice, very few people have become capable of doing ASD, much less doing it well. And, further, the likelihood is slim-to-none that the “very few” will grow to a significant number—relative to even a small fraction of the world’s burgeoning population—within the time window that is shrinking at an ever-increasing pace driven by escalating threats to sustainability. So, the relevant question is *not* how well does CSD stack up against ASD, but rather how well does CSD stack up against the “in widespread use” alternatives (like, say, Critical Success Factors thinking, or Spreadsheet thinking)?

I believe the answer is “very well!” I would much rather have many people drawing their spatial and temporal boundaries more broadly, making careful distinctions between stocks and flows, appreciating the difference between stock and flow-generated flows, and recognizing feedback loops when they see them, than not doing these things! I would much prefer that peoples’ mental simulations be underwritten by good stock/flow diagrams than implicit mish-mashes. Wouldn’t you?

Software can make it even better Being a technologist at heart, I believe it’s possible to bring technology to bear on improving the rigor and reliability that CSD can deliver—moving it even closer to what ASD can deliver, but without “paying the price.”

Because CSD appropriates pretty much wholesale the stock/flow language from ASD, the real leverage for producing “better results” does not lie in improving the *structure* of models built using these language elements. Instead, it lies in improving the *reliability of the dynamic inferences* that are drawn from simulating the resulting models. The important question thus becomes: Can technology be brought to bear on increasing the confidence one may place in the simulation results generated by CSD models?

I believe it can. By: (1) taking advantage of the restrictions imposed by removing converters/auxiliary variables from the stock/flow language, (2) making some inferences about what a person really means when they run multiple connectors into a flow regulator, and (3) providing some options for visually specifying direction-of-causality, and qualitative magnitudes, it should be possible to *automatically generate* a computer-based simulation of the system that’s being represented. The results will be qualitative patterns rather than quantitative values. The simulations can reveal things like “turning points,” oscillatory tendencies, bottlenecks, growth levers, and the like. The simulations cannot produce numerically accurate, or precise-timing, predictions. Leave these for ASD models.

But how reliable would the CSD-generated behavior patterns be? I would argue, on average, much more reliable than “in current use” mental simulation results. They’d also exceed the reliability of Systems Thinking-generated mental simulations, as well as mental simulations of CSD structures. But, again, they will continue to be less reliable than ASD-based computer simulations.

Is there a chance the CSD auto-simulated results could be misleading, or even downright "wrong"? Yep. But again, ask the same question of the "in current use" alternative! If you do, I believe you will agree that the chances for being misled and "wrong" are substantially greater there.

In conclusion If we lived in a Panglossian world, everyone, everywhere would build Analytical System Dynamics models and simulate them on computers so as to yield more reliable dynamic inferences. Were this the case, by the way, we'd probably also (albeit inadvertently) fix the population problem—i.e., there'd be precious little time left for "foolin' around!"

But, Pangloss is *not* writing our script. People *are* foolin' around—and not just with each other! We're foolin' with our global ecosystem (not to mention our local ones). We're also foolin' with our social, economic and political systems! And, if we continue to do so, we will continue to tax the limits of sustainability. Those limits are not infinite!

Conversational System Dynamics is no panacea. But it *is* capable of improving the framework of assumptions that a *large number of us* use to construct mental models. It's also capable of increasing the reliability of the dynamic inferences a *large number of us* draw from simulating these models. The key phrase in the two preceding sentences is "large number of us." That is to say, CSD, unlike ASD, is readily "gettable." And, once gotten, it also is more readily applied. By embracing CSD, people will have to give up some of the rigor and reliability they'd have gotten from employing ASD. But how many of them are going to be capable of employing ASD over, say, the time it takes for the next doubling of the world's population (which is to say, 25 years)? And, relative to the "in current use" alternative, people would gain some *very* substantial benefits from employing CSD!

Personally, I'll take the tradeoff. I have kids. I'm into sustainability.

Figure 1

Positioning the Alternatives in a Rigor/Reliability Two-Space

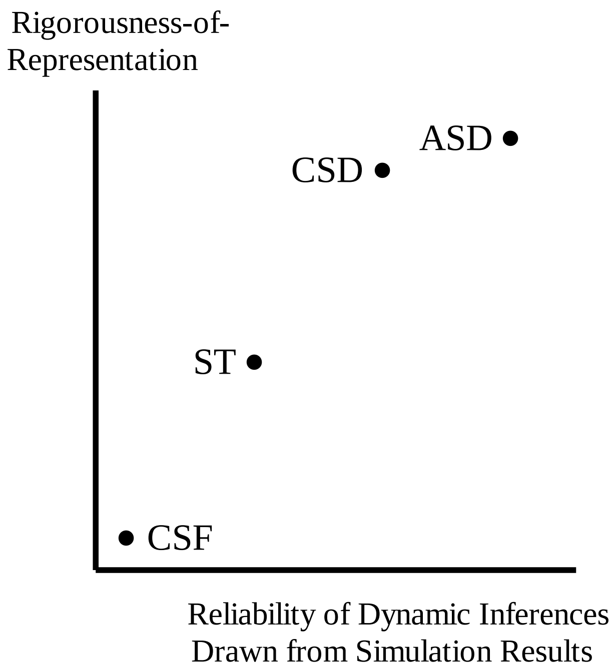


Table 1

What's in, What's out in Moving from Analytical to Conversational System Dynamics?

What's in?	**What's out?**
Stocks & flows (Operational Thinking)	Equations
Dimensional Consistency	Numbers
Conservation Laws	Converters
Stock-generated versus Flow-generated Flows	Quantitative Simulation
Feedback Loops (Closed-loop Thinking)	
Qualitative Simulation	

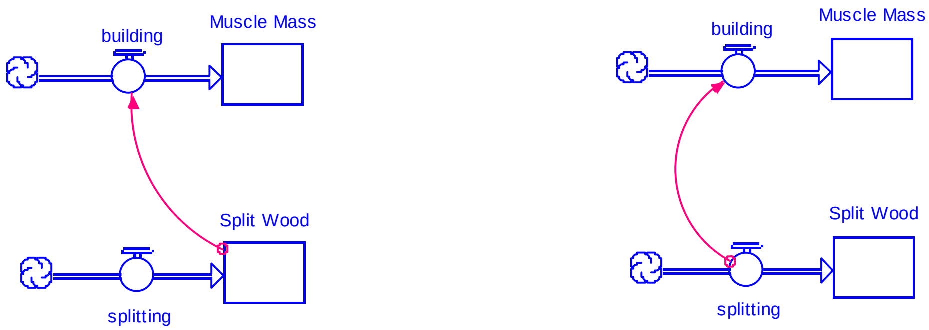
Table 2

A Comparison of Language Attributes

	Mathematics	Causal Loop Diagrams	Stock & flows
Simple		√	√
Operational			√
Visual		√	√
Rigorous	√		√

Figure 2

Illustrating Stock-generated versus Flow-generated Flows



A. Stock-generated

B. Flow-generated