

## Chapter 1

# Systems Thinking and the *STELLA* Software:

## *Thinking, Communicating, Learning and Acting More Effectively in the New Millennium*

I have been writing and re-writing this Guide for fifteen years. I always begin Chapter 1 by reeling off a litany of serious challenges facing humanity. And, you know what? The list has remained pretty much the same! There's homelessness and hunger, drug addiction and income distribution inequities, environmental threats and the scourge of AIDS. We've made precious little progress in addressing any of these issues over the last couple of decades! Indeed, you could make a strong case that, if anything, most (if not all) have gotten worse! And, some new challenges have arisen. Perhaps most disturbing among these is what appears to be (so far) largely an American phenomenon: kids killing kids (and teachers), at school.

So what's the problem? Why do we continue to make so little progress in addressing our many, very pressing social concerns?

My answer is that the way we *think*, *communicate*, and *learn* is outdated. As a result, the way we *act* creates problems. And then, we're ill-equipped to address them because of the way we've been taught to *think*, *communicate* and *learn*. This is a pretty sweeping indictment of some very fundamental human skills, all of which our school systems are charged with developing! However, it is the premise of this Chapter (and Systems Thinking) that it *is* possible to evolve our *thinking*, *communicating* and *learning* capacities. As we do, we will be able to make progress in addressing the compelling slate of issues that challenge our viability. But in order to achieve this evolution, we must overcome some formidable obstacles. Primary among these are the entrenched paradigms governing what and how students are taught. We *do* have the power to evolve these paradigms. It is now time to exercise this power!

I will begin by offering operational definitions of *thinking*, *communicating* and *learning*. Having them will enable me to shine light on precisely what skills must be evolved, how current paradigms are thwarting this evolution, and what Systems Thinking and the *STELLA* software can do to help. Finally, I'll overview what's to come in the remainder of the Guide. In the course of this Chapter, I will identify *eight* Systems Thinking skills. They are: 10,000 Meter,

System as Cause, Dynamic, Operational, Closed-loop, Non-linear, Scientific, and Empathic Thinking. Each will reappear, some receiving more attention than others, throughout the Guide. It is mastery of these skills that will enable you to make effective use of the *STELLA* software.

## Providing Operational Definitions

The processes of thinking, communicating, and learning constitute an *interdependent system*, or at least have the potential for operating as such. They do not operate with much synergy within the current system of formal education. The first step toward realizing the potential synergies is to clearly visualize how each process works in relation to the other. I'll use the *STELLA* software to help with the visualization...

## Thinking

Thinking...we all do it. But what is it? The dictionary says it's "...to have a thought; to reason, reflect on, or ponder." Does that clear it up for you? It didn't for me.

I will define thinking as consisting of two activities: *constructing* mental models, and then *simulating* them in order to draw conclusions and make decisions. We'll get to constructing and simulating in a moment. But first, what the heck is a *mental model*?

It's a "selective abstraction" of reality that you create and then carry around in your head. As big as some of our heads get, we still can't fit reality in there. Instead, we have *models* of various aspects of reality. We simulate these models in order to "make meaning" out of what we're experiencing, and also to help us arrive at decisions that inform our actions.

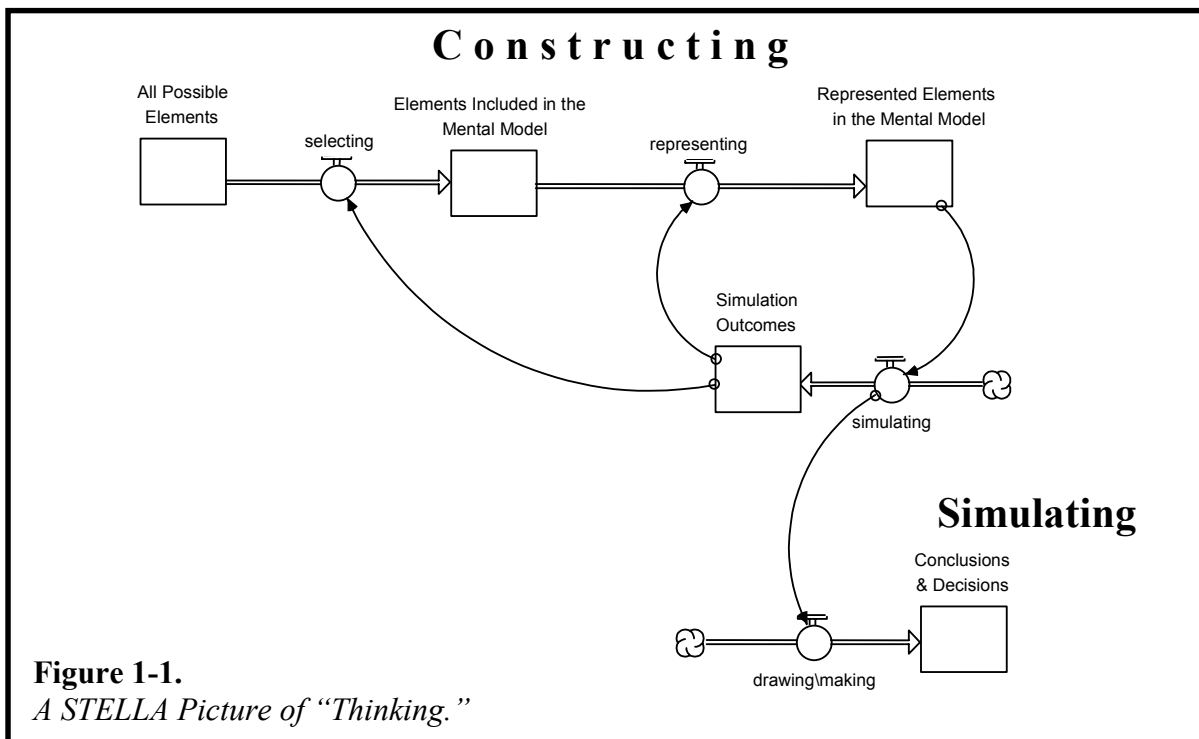
For example, you have to deal with your kid, or a sibling, or your parent. None of them are physically present inside your head. Instead, when dealing with them in a particular context, you select certain aspects of each that are germane to the context. In your mind's eye, you relate those aspects to each other using some form of cause-and-effect logic. Then, you *simulate* the interplay of these relationships under various "what if" scenarios to draw conclusions about a best course of action, or to understand something about what has occurred.

If you were seeking to understand why your daughter isn't doing well in arithmetic, you could probably safely ignore the color of her eyes when selecting aspects of reality to include in the mental model you are constructing. This aspect of reality is unlikely to help you in developing an understanding of the causes of her difficulties, or in drawing conclusions about what to do. But, in selecting a blouse for her birthday? Eye color probably ought to be in *that* mental model.

As the preceding example nicely illustrates, all models (mental and otherwise) are simplifications. They necessarily omit many aspects of

the realities they represent. This leads to a very important statement that will be repeated several times throughout this Guide. The statement is a paraphrase of something W. Edwards Deming (the father of the “Quality movement”) once uttered: “*All models are wrong, some models are useful.*” It’s important to dredge this hallowed truth back up into consciousness from time to time to prevent yourself from becoming “too attached” to one of your mental models. Nevertheless, despite the fact that all models are wrong, *you have no choice but to use them*—no choice that is, if you are going to *think*. If you wish to employ non-rational means (like gut feel and intuition) in order to arrive at a conclusion or a decision, no mental model is needed. But, if you want to think...you can’t do so without a mental model!

Figure 1-1 presents a *STELLA* map of the activities that comprise “thinking:” *constructing* (a mental model), and *simulating* in order to draw conclusions. As the Figure indicates, constructing is divided into two sub-activities: *selecting* and *representing*. The first sub-activity answers the question: *What should I include in my mental model?* The second sub-activity answers the question: *How should I represent what I include?* These are the two fundamental questions that must be answered in constructing *any* mental model. It is my conviction that the paradigms currently governing teaching in our schools restrict development of the whole set of skills needed to become effective in executing both the constructing and simulating activities. That is, our schools are thwarting development of thinking capacity—something no school board would approve, and we can ill afford!

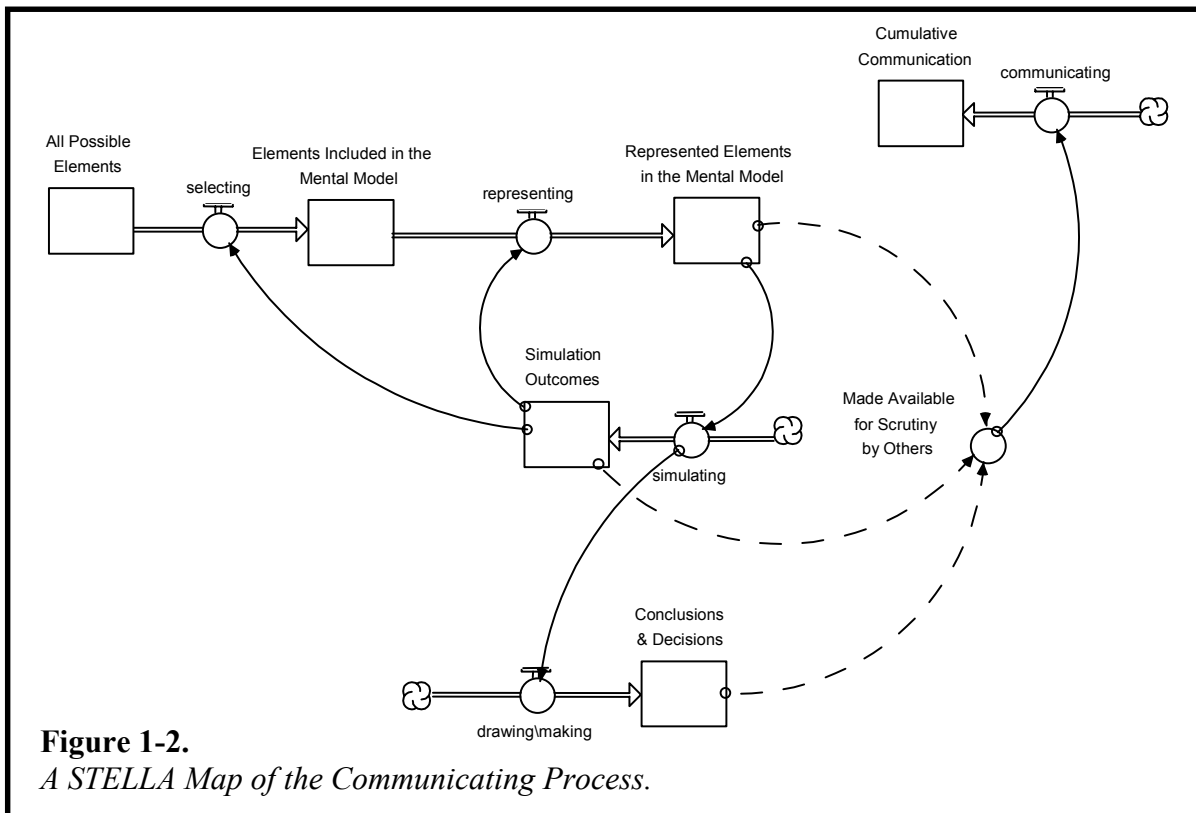


**Figure 1-1.**  
A STELLA Picture of “Thinking.”

The “wire” that runs from *Represented Elements in the Mental Model* to *simulating* is intended to suggest that *simulating* cannot proceed until a mental model is available—which is to say, the *selecting* and *representing* activities have been executed. Simulating yields conclusions that, among other things, help us to make decisions. But, as Figure 1-1 indicates, simulation outcomes play another important role in the thinking process. They provide feedback to the *selecting* and *representing* activities (note the “wires” running from *Simulation Outcomes* to the two activities). Simulation outcomes that make no sense, or are shown to have been erroneous, are a signal to go back to the drawing board. Have we left something out of our mental model that really should be in there, or included something that really doesn’t belong? Have we misrepresented something we have included? This self-scrutiny of our mental models, inspired by simulation outcomes, is one of the important ways we all *learn*...but we’re getting ahead in the story. Before we discuss *learning*, let’s look at *communicating*.

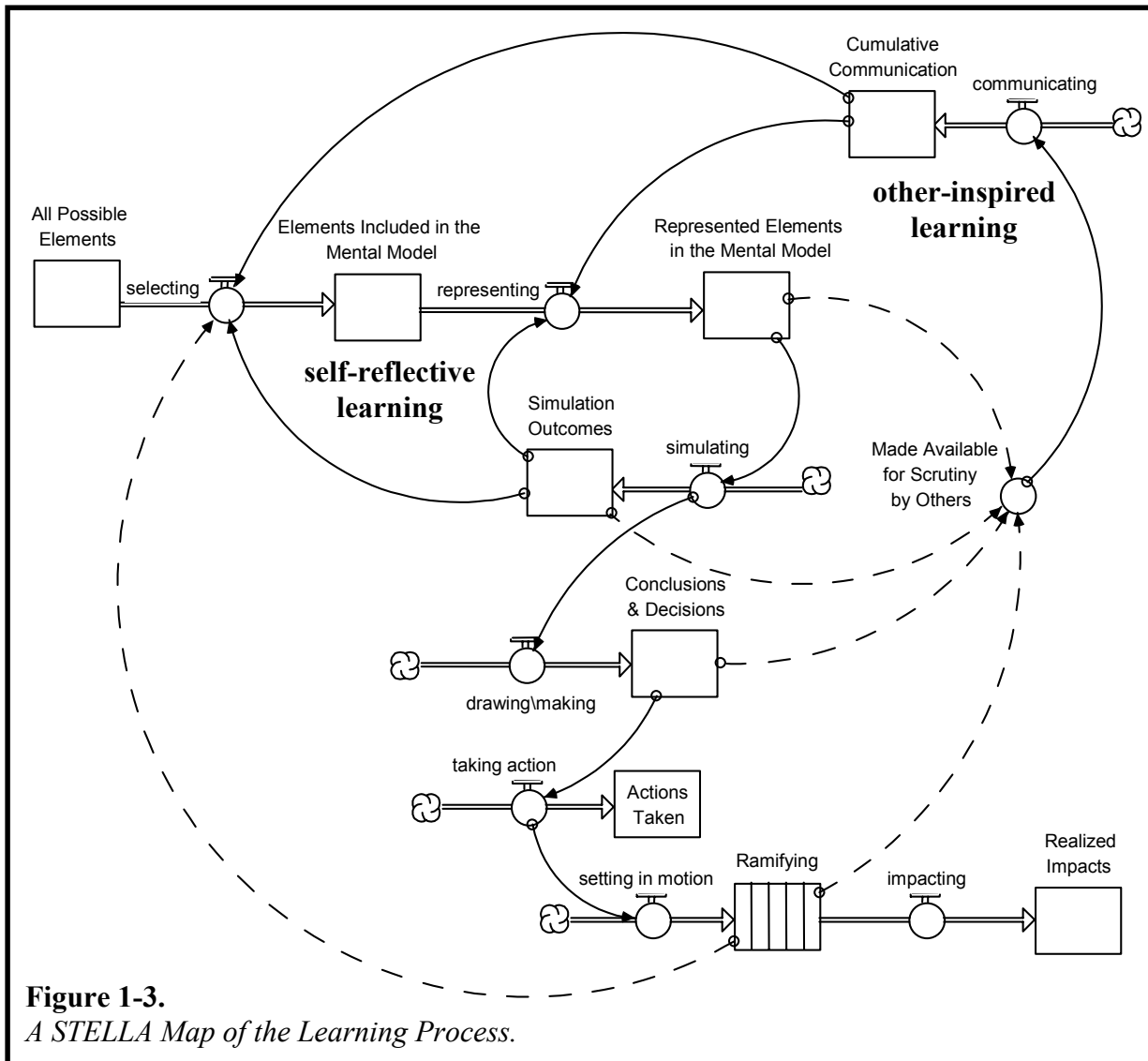
### *Communicating*

An operational picture of communicating is presented in Figure 1-2. The first thing to note is that the figure includes the elements that make up the *thinking* activity. The intention is to suggest that *communicating* is inextricably linked to *thinking*. Indeed, as the variable *Made Available for Scrutiny by Others* indicates, the outputs of the Thinking process provide the raw material for the Communicating process. Three sources of “raw material” are illustrated in the Figure: the mental model, the associated simulation outcomes, and the conclusions that have been drawn from simulating. By making these sources available, others then can “think” about them! Specifically, they can compare them to the corresponding information they possess. The comparison process, as you are about to see, drives a second type of *learning*!



*Learning*

Learning is depicted in Figure 1-3. It's a pretty elaborate picture, and a good example of one that should be unfurled one chunk at a time using the *STELLA* software's storytelling feature, than sprung on you full-blown. If you *would* prefer to see the Figure 1-3 story "unfurled," open the model named "Learning" in the *Intro to Systems Thinking* folder, and the experience can be yours!



**Figure 1-3.**  
*A STELLA Map of the Learning Process.*

The first type of learning was identified in the discussion of the *Thinking* process. Call it *self-reflective learning*. It comes about when simulation outcomes are used to drive a process in which a mental model's content, and/or representation of content, is changed. I've also just alluded to a second type of learning...one that's driven by the *Communicating* process. Call it *other-inspired learning*. As Figure 1-3 suggests, the raw material for this type of learning is: the mental model itself, the simulation outcomes associated with that model, and/or the conclusions drawn from simulating. How much learning occurs, depends upon both the quality of the feedback provided—where "quality" includes both content and "packaging"—as well as the willingness and ability to "hear" the feedback.

Figure 1-3 also adds a fourth source of raw material for learning: the impacts of one's actions. As the Figure suggests, often it is difficult to

perceive the full impact because ramifying takes a long time, and spreads out over a great distance. To reflect this fact, the information for this type of learning is shown as radiating off the “conveyor” named *Ramifying*, rather than the stock called *Realized Impacts*. [NOTE: Conveyors are used to represent delays].

It’s useful to spend a little time digesting Figure 1-3—which shows the thinking, communicating and learning *system*. An important thing to note about the Figure is that all roads ultimately lead back to learning—which is to say, *improving the quality of the mental model*. Learning occurs when either the content of the mental model changes (via the *selecting* flow), or the representation of the content changes (via the *representing* flow). By the way, to make the figure more readable, not all wires that run to the *representing* flow have been depicted.

There are two important take-aways from the Figure. First, the three processes—*thinking*, *communicating* and *learning*—form a self-reinforcing system. Building skills in any of the three processes helps build skills in *all* three processes! Second, unless a mental model changes, *learning does not occur!*

I will now use the preceding definitions of thinking, communicating and learning as a framework for examining how well the current system of formal education is preparing our youth for the issues they’ll face as citizens in the new millennium. Wherever I indict the system, I’ll also offer alternatives. The alternatives will emanate out of a framework called Systems Thinking, and make use of the *STELLA* software as an implementation tool. I’ll begin with a blanket indictment, and then proceed using the thinking/communicating/learning framework to organize specific indictments.

## **The Blanket Indictment**

If schools were mandated to pursue anything that looked remotely close to Figure 1-3, I wouldn’t be writing this Chapter! Instead, students spend most of their time “assimilating content,” or stated in a more noble-sounding way, “acquiring knowledge.” And so, the primary learning activity in our schools is *memorizing!* It’s flipping flash cards, or repeating silently to yourself over and over, the “parts of a cell are...,” the “three causes of World War II are...,” the “planets in order away from the sun are...” Students cram facts, terms, names, and dates in there, and then spit them back out in the appropriate place on a content-dump exam. This despite the fact that students perceive much of the content to have little perceived relevance to their lives, and that a good chunk of the content will be obsolete before students graduate.

Notice something about the process of “acquiring knowledge.” It bears no resemblance to the process depicted in Figure 1-3. In acquiring knowledge, no mental model is constructed. No decisions

are made about what to include, or how to represent what's included. No mental simulating occurs. Acquiring knowledge also doesn't require, or benefit from, communicating. Quite the contrary, the knowledge acquisition process is solitary, and *non-thinking* in nature. And then, the coup de gras...Will *content* really equip our young people for effectively addressing the issues they'll face in the new millennium?

It's important to recognize that although I am indicting the content-focus of our education system, I am not indicting the teachers who execute that focus (at least not all of them)! Pre-college teachers, especially, are hamstrung by rigid State (and in some cases, Federal) mandates with respect to material to be taught, pedagogic approach, and even sequencing. My indictment is primarily aimed at the folks who are issuing these mandates! I'm indicting those who have established measurement systems that employ a content-recall standard for assessing mastery, and who confuse "knowing" with "understanding" and "intelligence." To you, I wish only to say (loudly): *Wake Up!*

That said, let's get on with some specific indictments, and with suggestions for doing something to improve the situation.

Whether the mental model being constructed is of an ecosystem, a chemical reaction, a family, or a society, three fundamental questions must always be answered in constructing it. They are: (1) What elements should be included in the model—or, the flip side—what elements should be left out? (2) How should the elements you decide to include be represented? (3) How should the relationships between the elements be represented?

Deciding what to include in a mental model, in turn, breaks into two questions. *How broadly do you cast your net?* This is a "horizontal" question. And, *how deeply do you drill?* This is a "vertical" question. Developing good answers to these two questions requires skill. And, like any skill, this one must first be informed by "good practice" principles, and then honed through repeated practice. Let's see how development of the "what to include?" skills fares in the current education system.

The first thing to note is that little time remains for developing such skills because so much time is allocated to stuffing content—which as noted, is an activity that does not require "what to include/how to represent" choices. Nevertheless, the formal education system *does* leave its stamp on *selection* skills. And, it's not a particularly useful one!

One of the implicit assumptions in the prevailing educational paradigm is that what's knowable should be *segmented*. The rationale appears to be that it will enable content to be assimilated most efficiently. The

**Thinking:  
Constructing  
a Mental  
Model**

*What to  
Include?*



resulting student learning strategy might be called: “Divide & Conquer.” Those who are best at executing this strategy reveal their expertise at mid-term and final time, effecting a serial, single-content focus—e.g., putting assimilated history content aside, in order that it not interfere with imbibing biology content. Over time, students figure out which content areas they’re “best at,” and then concentrate on these. The result is that students become *content specialists*. At the same time populations of math-phobics, literature-phobics, language-phobics, and science-phobics are created. Students come to see the world as divided into “content bins,” some of which they “like,” others of which, they avoid.

Content specialists tend to cast their nets narrowly (over the domains they “know”). And, they also tend to focus their gaze deeply—they’ve stored lots of detail about their “comfort” arena(s). Their mental models thus tend to be narrow and deep. They contain a lot...about a little. Meanwhile, students’ skills in seeing *horizontal* connections never really develop. Instead, vertical detail dominates big picture.

The problem with this approach to developing student thinking capacity is that *all* of the challenges I ticked off at the start of the Chapter—homelessness, income distribution inequity, global warming, AIDS, kids killing kids, etc.—are *social* in nature! They arise out of the interaction of human beings with each other, with the environment, with an economy. They are problems of *interdependency*! They are horizontal problems! That’s because the horizontal boundaries of social systems, in effect, go on forever. Make a change within a particular organization, for example, and the ripple effects quickly overflow the boundaries of the organization. Each employee interacts with a raft of people outside the organization who, in turn, interact with others, and so on. So, in the social domain, being able to think *horizontally* is essential! Nets must be cast broadly, before drilling very deep into detail. Yet, to the extent students’ selection skills are being developed at all, they are being biased in exactly the *opposite* direction...toward bin-centricity.

Systems Thinking offers three thinking skills that can help students to become more effective in answering the “what to include” question. They are: “10,000 Meter,” “Systems as Cause,” and “Dynamic” Thinking.

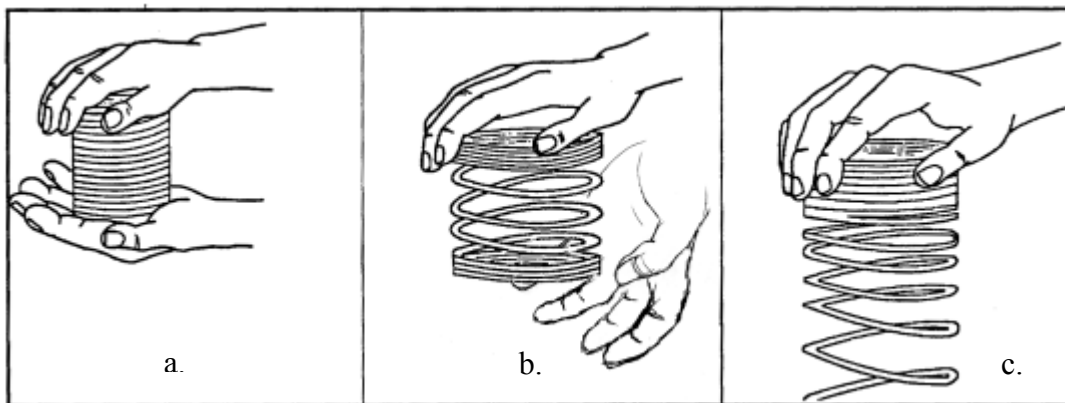
### *10,000 Meter Thinking*

The first thinking skill, 10,000 Meter Thinking, was inspired by the view one gets on a clear sunny day when looking down from the seat of a jet airliner. You see horizontal expanse, but little vertical detail. You gain a “big picture,” but relinquish the opportunity to make fine discriminations.

*System as Cause Thinking*

The second Systems Thinking skill, “System as Cause” Thinking, also works to counter the vertical bias toward including too much detail in the representations contained in mental models. “System as Cause” thinking is really just a spin on Occam’s razor (i.e., the *simplest* explanation for a phenomenon is the *best* explanation). It holds that mental models should contain only those elements whose interaction is capable of *self-generating* the phenomenon of interest. It should not contain any so-called “external forces.” A simple illustration should help to clarify the skill that’s involved.

Imagine you are holding slinky as shown in Figure 1-4a. Then, as shown in Figure 1-4b, you remove the hand that was supporting the device from below. The slinky oscillates as illustrated in Figure 1-4c. The question is: *What is the cause of the oscillation?* Another way to ask the question: *What content would you need to include in your mental model in order to explain the oscillation?*



**Figure 1-4.**  
*A Slinky Does Its Thing.*

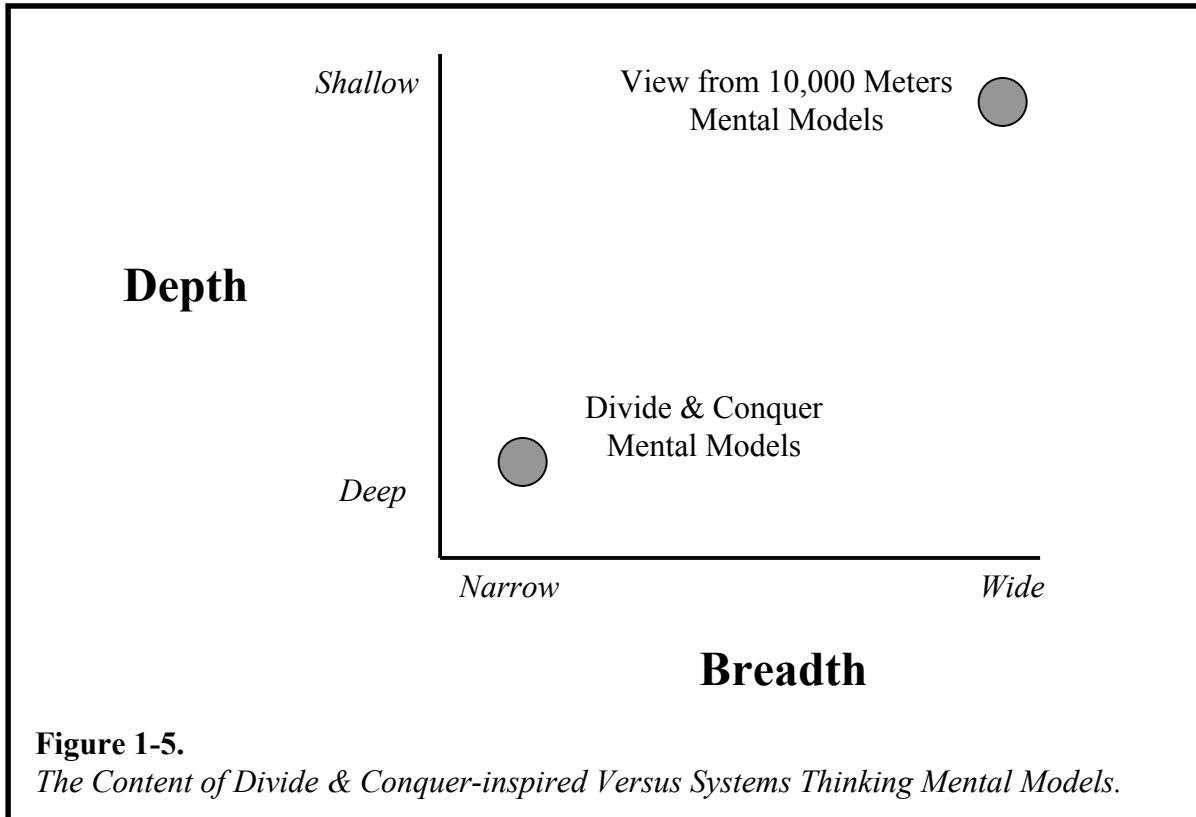
The two, most common causes cited are: gravity, and removal of the hand. The “System as Cause” answer to the question is: the slinky! To better appreciate the merits of this answer, imagine that you performed the exact same experiment with, say, a cup. The outcome you’d get makes it easier to appreciate the perspective that the oscillatory behavior is latent within the structure of the slinky itself. In the presence of gravity, when an external stimulus (i.e., removing the supporting hand) is applied, the dynamics latent within the structure are “called forth.” It’s not that gravity and removal of the hand are irrelevant. However, they wouldn’t appear as part of the “causal content” of a mental model that was seeking to explain why a slinky oscillates.

The third of the so-called “filtering skills” (Systems Thinking skills that help to “filter” out the non-essential elements of reality when constructing a mental model) is called “Dynamic Thinking.” This skill provides the same “distancing from the detail” that 10,000 Meter Thinking provides, except that it applies to the behavioral—rather than the structural—dimension.

Just as perspectives get caught-up in the minutiae of structure, they also get trapped in “events” or “points,” at the expense of seeing patterns. In history, students memorize dates on which critical battles were fought, great people were born, declarations were made, and so forth. Yet in front and behind each such “date” is a pattern that reflects continuous build-ups or depletions of various kinds. For example, the US declared its independence from England on July 4, 1776. But prior to that specific date, tensions built continuously between the two parties to the ensuing conflict. In economics, the focus is on equilibrium *points*, as opposed to the trajectories that are traced as variables move between the points.

Dynamic Thinking encourages one to “push back” from the events and points to see the pattern of which they are a part. The implication is that mental models will be capable of dealing with a dynamic, rather than only a static, view of reality.

Figure 1-5 should help make clearer the difference between the “Divide & Conquer”-inspired viewpoint and the Systems Thinking-inspired perspective in terms of the resulting content of a mental model. The Figure makes the contrast between mental models constructed using the alternative perspectives look pretty stark. That’s an accurate picture. Yet there is nothing to prevent models forged using *both* perspectives from co-existing within a single individual. Nothing, that is, but finding room for developing the three associated Systems Thinking skills (10,000 Meter, System as Cause, and Dynamic Thinking) in a curriculum already overstocked with mandated discipline-focused “knowledge acquisition” requirements. To be sure, there have always been (and will always be) efforts made to develop horizontal thinking skills, usually in the form of cross-disciplinary offerings. But such efforts are scattered, and rely heavily on the “extra-curricular” commitment and enthusiasm of particular individuals. And, they grow increasingly rare as grade levels ascend, being all but non-existent at the post-secondary level.



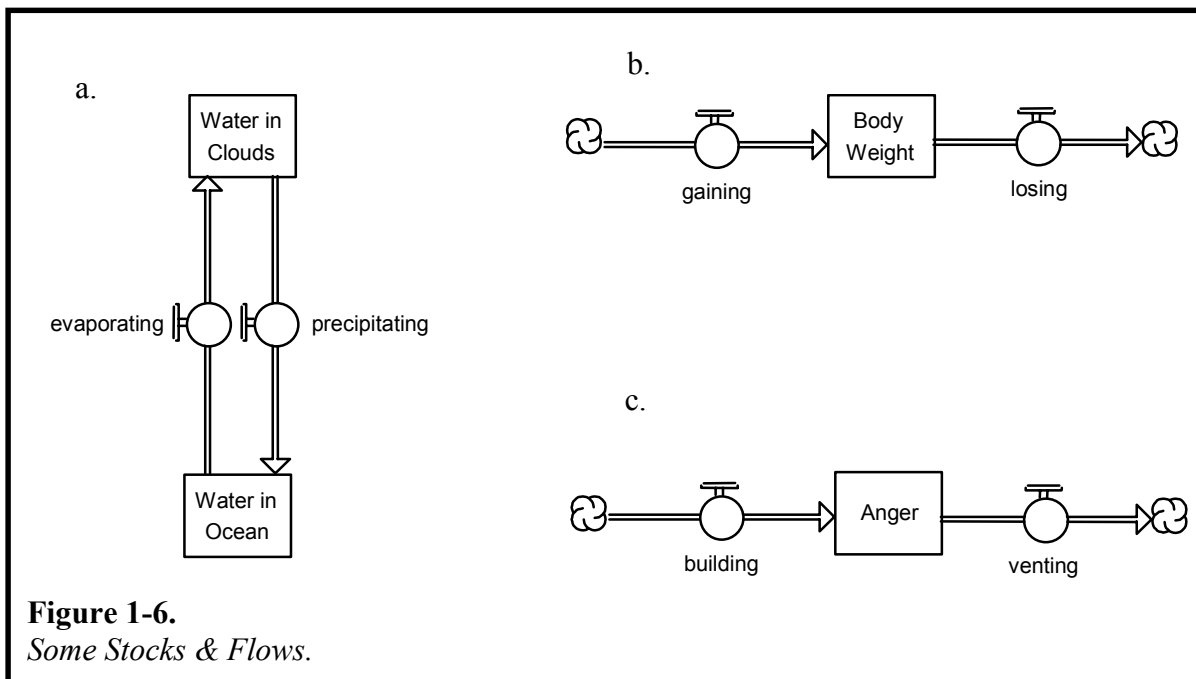
*How to  
Represent  
What You  
Include*

Until the average citizen can feel comfortable embracing mental models with horizontally-extended/vertically-restricted boundaries, we should not expect *any* significant progress in addressing the pressing issues we face in the social domain. And until the measurement rubrics on which our education system relies are altered to permit more focus on developing horizontal thinking skills, we will continue to produce citizens with predilections for constructing narrow/deep mental models. The choice is ours. Let's *demand* the change!

Once the issue of *what* to include in a mental model has been addressed, the next question that arises is how to represent what has been included. A major limit to development of students' skills in the representation arena is created by the fact that each discipline has its own unique set of terms, concepts, and in some cases, symbols or icons for representing their content. Students work to internalize each content-specific vocabulary, but each such effort contributes to what in effect becomes a *content-specific* skill.

Systems Thinking carries with it an icon-based lexicon called the language of "stocks and flows." This language constitutes a kind of *Esperanto*, a lingua franca that facilitates *cross-disciplinary* thinking and hence implementation of a "horizontal" perspective. Mental models encoded using stocks and flows, *whatever the content*, recognize a fundamental distinction among the elements that populate them. That distinction is between things that accumulate (called

“stocks”) and things that flow (called “flows”). Stocks represent conditions within a system—i.e., how things are. Flows represent the activities that cause conditions to change. Some examples of accumulations are: water in a cloud, body weight, and anger. The associated flows are: evaporating/precipitating, gaining/losing, and building/venting. Figure 1-6 should help you to develop a clearer picture of the distinction between a stock and a flow.



**Figure 1-6.**  
Some Stocks & Flows.

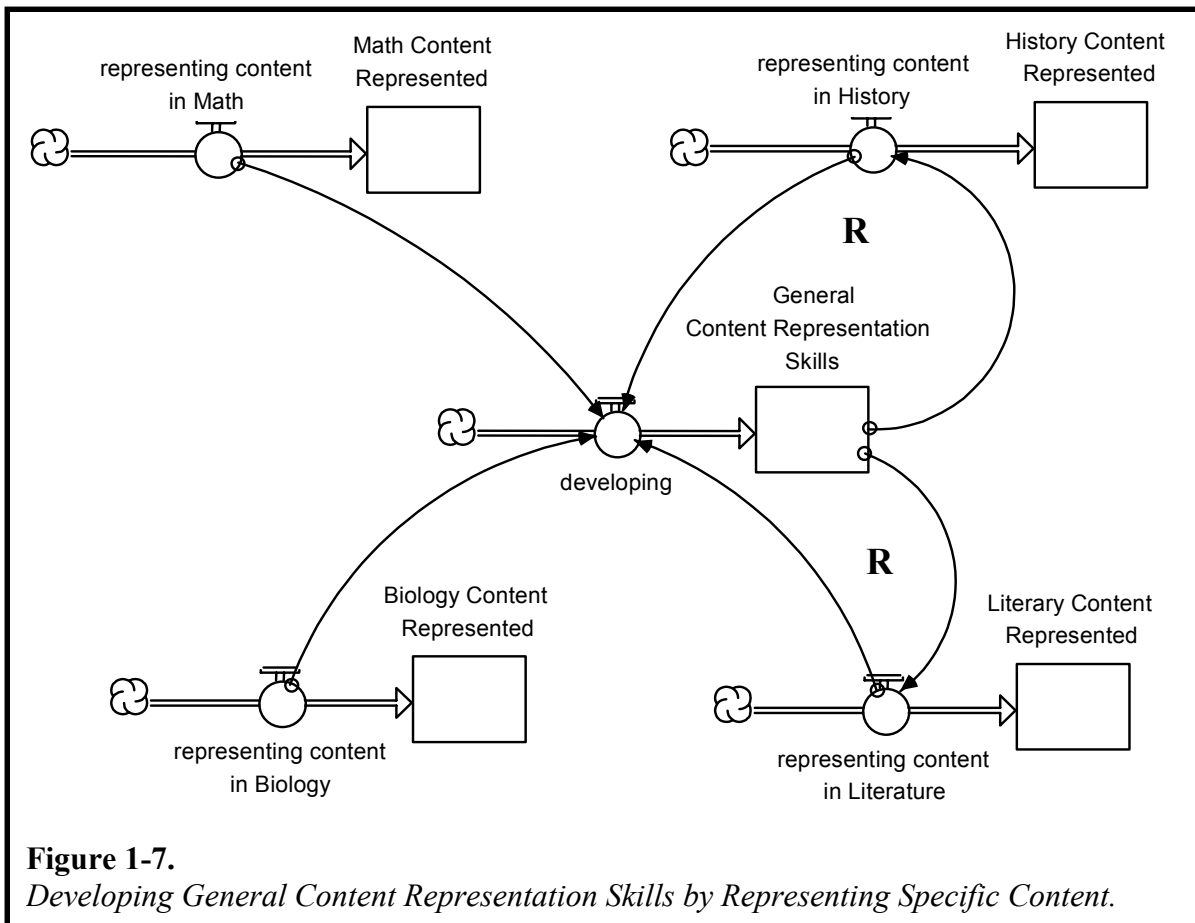
To gain a quick idea of why the distinction matters, consider the illustration in Figure 1-6b. Suppose a person whose weight has been increasing, decides to take some action to address the situation. First, they successfully eliminate *all* junk food snacks from their diet, and do not eat more at regular meals to compensate for doing so. Second, they implement a rigorous aerobic exercise program—to which they religiously adhere. This means the person will have lowered the volume of the *gaining* flow (i.e., reduced caloric intake) and increased the volume of the *losing* flow (increased caloric expenditure).

So what happens to this person’s body weight?

Did your answer include the possibility that it would still be increasing? It should have! Look at Figure 1-6b. The reason the person may still be gaining weight is because decreasing the rate of *gaining* (the inflow), and increasing rate of *losing* (the outflow), will only cause *Body Weight* (the stock) to decrease if *gaining* actually drops below *losing*. Until this occurs, the person will continue to gain weight—albeit at a slower rate! Take a moment to make sure you understand this reasoning before you proceed.

When the distinction between stocks and flows goes unrecognized—in this example, and in any other situation in which mental simulations must infer a dynamic pattern of behavior—there is a significant risk that erroneous conclusions will be drawn. In this case, for example, if the inflow and outflow volumes do not cross after some reasonable period of time, the person might well conclude that the two initiatives they implemented were ineffective and should be abandoned. Clearly that is not the case. And, just as often, the other type of erroneous conclusion is drawn: “We’re doing the right thing, just not enough of it!” Redoubling the effort, in such cases, then simply adds fuel to the fire.

In addition to helping increase the reliability of mental simulations, using stocks and flows in representing the content of a mental model has another very important benefit. The benefit derives from the fact that the concepts of accumulation and flow are *content-independent*. Therefore, in whatever specific content arena they are used, the use contributes to building the *general* content-representation skill! Figure 1-7 seeks to capture this idea via the links that run from each of four content-specific representing activities to the building of a general content-representation skill.



There's a second important idea illustrated in Figure 1-7. Note the two "R's." They stand for the word "Reinforcing"—which is the type of *feedback loop* they designate. The loops work like this...

As *general* content representation skills build, they facilitate each specific content-representing activity—though, to keep the picture simple, the link to only two of the specific arenas is illustrated. Then, as students engage in *specific* content-representation activities, because they are using a content-transcendent language to do so, they develop *general* content representation skills—a *virtuous learning cycle*! The cycle creates synergy because *all* content arenas benefit from activities that go on in *any one* of them! Now, instead of one content arena *interfering* with learning in another, each helps to accelerate learning in each of the others.

### *Operational Thinking*

To be able to "speak/write" effectively in the language of stocks and flows requires that students build a fourth Systems Thinking skill, a *very* important one: *Operational Thinking*. Much of Chapters 2-7 are taken up with developing this skill, so I'll not say any more about it here. Teaching the language of stocks and flows, and the associated Operational Thinking skills, at an early point in the formal education process (e.g., fourth, fifth, sixth grade) would be a huge step toward enabling students to develop a better set of *representing* skills. It would, at the same time, leverage development of students' horizontal thinking skills. And the good news is that at the lower grade levels, there still remains sufficient flexibility in many curricula to permit taking this step. *Carpe diem!*

### *How to Represent the Relationships Between Elements that You Include*

The final question we must answer in constructing a mental model is how to represent the *relationships* between the elements we decide to include. In answering this question, we must necessarily make some assumptions about the general nature of these relationships. Among the most sacred of all the covenants that bind members of a society together is the implicit agreement about how such relationships work. In Western cultures, the implicit agreement is that reality works via a structure of serial cause-and-effect relationships. Thus-and-such happens, which leads this-and-such to occur, and so forth. Not all cultures "buy" serial cause-and-effect (some subscribe to perspectives such as "synchronicity" and "God's hand"). But Western culture does.

I have no beef with serial cause-and-effect. It's a useful viewpoint. However, when I look more closely at the assumptions that characterize the particular brand of it to which Western culture subscribes, I discover that these assumptions seriously restrict learning! Let's see how...

The name I use for the Western brand of serial cause-and-effect is "Laundry List Thinking" (another name would be "Critical Success Factors Thinking"). Laundry List Thinking is defined by a set of four

“meta” assumptions that are used to structure cause-and-effect relationships. I use the term “meta” because these assumptions are *content-transcendent*. That is, we use them to structure cause-and-effect relationships whether the content is Literature, Chemistry, or Psychology, and also when we construct mental models to address personal or business issues. Because we all subscribe to these “meta” assumptions, and have had them inculcated from the “get go,” we are essentially unaware that we even use them! They have become so obviously true they’re not even recognized as assumptions any more. Instead, they seem more like attributes of reality.

But, as you’re about to see, the “meta” assumptions associated with Laundry List Thinking are likely to lead to structuring relationships in our mental models in ways that will cause us to draw erroneous conclusions when we simulate these models. I will identify the four “meta” assumptions associated with Laundry List Thinking, and then offer a Systems Thinking alternative that addresses the shortcomings of each. Here’s a question that I’ll use to surface all four assumptions...

*What causes students to succeed academically?* Please take a moment and actually answer the question.

Before I proceed with harvesting the question, I want to provide some evidence to suggest the Laundry List framework is in very widespread use both in academic and non-academic circles.

On the non-academic side, “recipe” books continue to be the rage. One of the first, and most popular, of these is Stephen Covey’s *The Seven Habits of Highly Effective People*. The habits he identifies are nothing more (nor less) than a laundry list! And, for those of you familiar with the “critical success factors” framework, it, too, is just another name for a laundry list. In the academic arena, numerous theories in both the physical and social sciences have been spawned by Laundry List Thinking. For example, one very popular statistical technique known as “regression analysis,” is a direct descendent of the framework. The “Universal Soil Loss” equation, a time-tried standard in the geological/earth sciences, provides a good illustration of a regression analysis-based, Laundry List theory. The equation explains erosion (A, the *dependent* variable) as a “function of” a list of “factors” RKLSCP (the *independent* variables):



**A=RKLSCP**

**A** soil loss /unit of area

**R** rainfall

**K** soil erodibility

**L** slope length

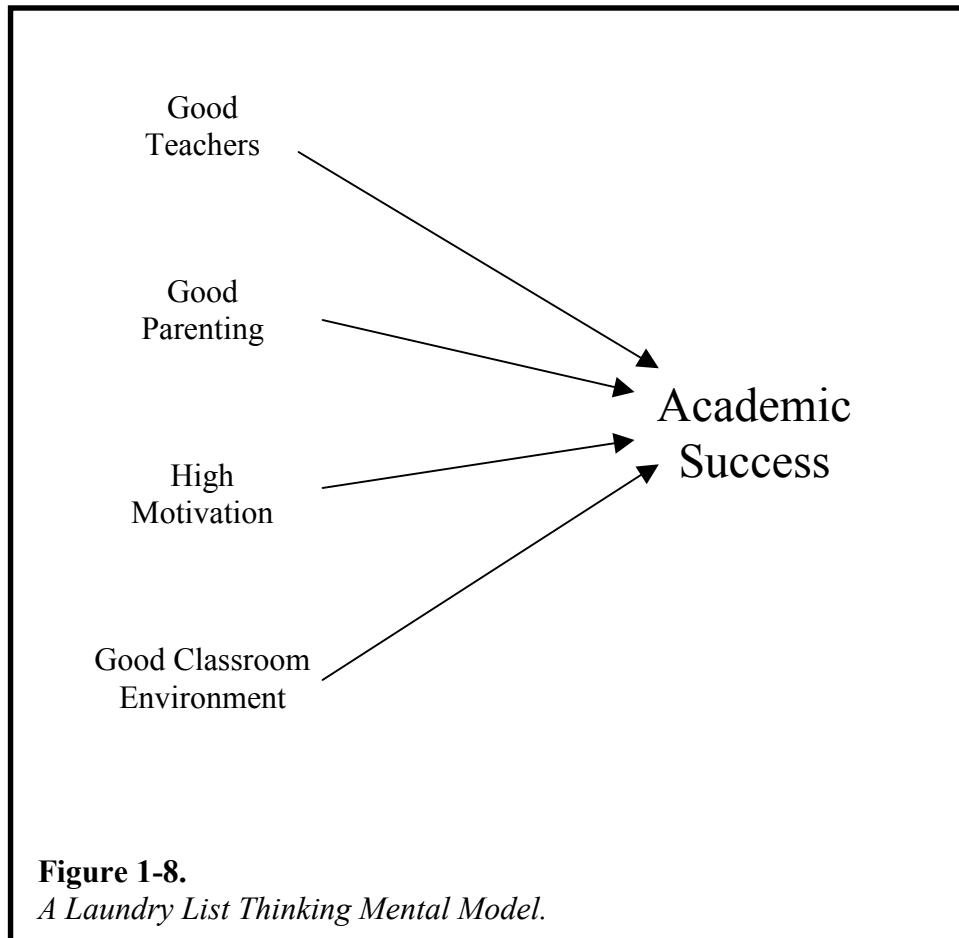
**S** slope gradient

**C** crop management

**P** erosion control practice

Okay, so now that I've provided some evidence that Laundry List Thinking is quite widespread, you shouldn't feel bad if you (like most people) produced a laundry list in response to the "*What causes students to succeed academically?*" question.

If you did produce such a list, it probably included some of the variables shown on the left-hand side of Figure 1-8. The Figure belies *four* "meta" assumptions about cause-and-effect relationships implicit in the Laundry List framework. Let's unmask them!

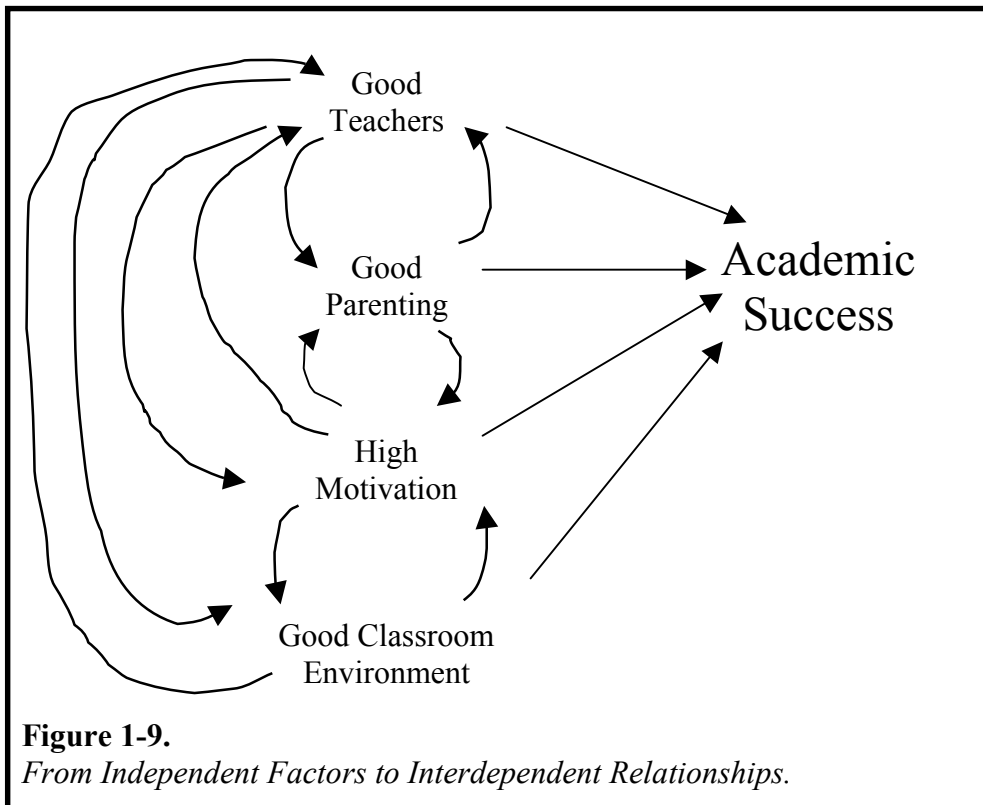


**Figure 1-8.**  
*A Laundry List Thinking Mental Model.*

The first “meta” assumption is that the causal “factors” (four are shown in Figure 1-8) each operate *independently* on “the effect” (“academic success” in the illustration). If we were to “read the story” told by the view depicted in the Figure, we’d hear: “Good Teachers cause Academic Success; Good Parenting cause...” Each factor, or independent variable, is assumed to exert its impact *independently* on Academic Success, the *dependent* variable.

To determine how much sense this “independent factors” view really makes, please consult *your* experience...

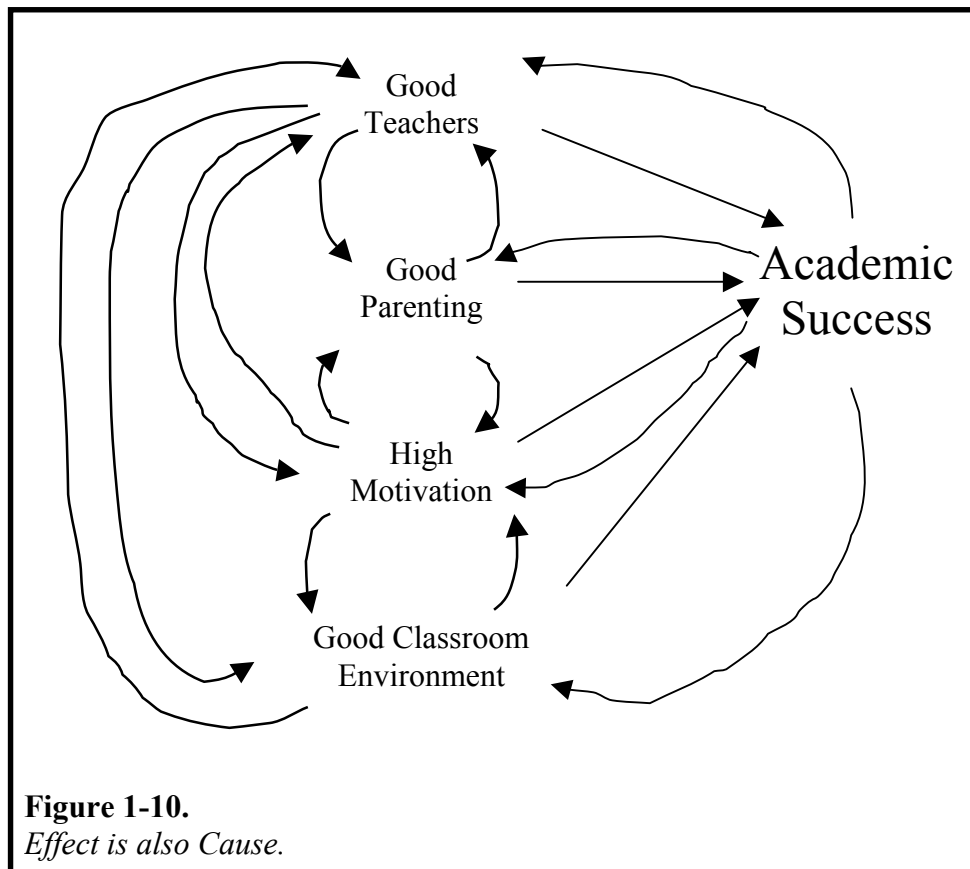
Isn't it really a “partnership” between teachers and parents (good open lines of *reciprocal* communication, trust, etc.) that enables both parties to contribute effectively to supporting a student's quest for academic success? And don't good teachers really help to create both high student motivation and a good classroom environment? Isn't it the case that highly motivated students and a good classroom environment make teaching more exciting and enjoyable, and as a result cause teachers to do a better job? I could continue. But I suspect I've said enough to make the point. The four factors shown in Figure 1-8 aren't even close to operating *independently* of each other! They operate as a tightly intertwined set of *interdependent* relationships. They form a *web of reciprocal causality*! The picture that emerges looks much more like Figure 1-9, than Figure 1-8!



**Figure 1-9.**  
*From Independent Factors to Interdependent Relationships.*

So, there goes the first “meta” assumption associated with Laundry List Thinking (i.e., that the causal “factors” operate *independently*). Now let’s watch the second Laundry List “meta” assumption bite the dust! The second assumption is that *causality runs one-way*. Look back at Figure 1-8. Notice that the arrows all point from cause to effect; all run from left to right. Now steal another glance at Figure 1-9. Notice anything different?

That’s right, the arrows linking the “causes” now run *both ways*! Cause-and-effect comes in *loops*! As Figure 1-10 shows, once circular cause-and-effect enters the picture, the so-called “effect” variable also loses its “dependent” status. It, too, now “causes”—which is to say that academic success stimulates student motivation and a good classroom environment, just as much as they drive it. Academic success also causes teachers to perform better—it’s easier to teach students who are doing well—just as much as good teachers create academic success. And so forth. “Academic Success” is just as much a *cause* of any of the four “factors” as they are a cause of it! And so, independent and dependent variables become chickens and eggs. Everybody becomes a co-conspirator in a causal web of interrelationships.



**Figure 1-10.**  
*Effect is also Cause.*

*Closed-loop  
Thinking*

The shift from the Laundry List—causality runs one-way—view, to System Thinking’s two-way, or closed-loop, view is a big deal! The former is *static* in nature, while the latter offers an “ongoing process,” or *dynamic*, view. Viewing reality as made up of a web of *closed loops* (called *feedback loops*), and being able to structure relationships between elements in mental models to reflect this, is the fifth of the Systems Thinking skills. It’s called *Closed-loop Thinking*. Mastering this skill will enable students to conduct more reliable mental simulations. Initiatives directed at addressing pressing social issues will not be seen as “one-time fixes,” but rather as “exciting” a web of loops that will continue to spin long after the initiative is activated. Developing closed-loop thinking skills, will enable students to better anticipate unintended consequences and short-run/long-run tradeoffs. These skills also are invaluable in helping to identify high-leverage intervention points. The bottom line is an increase in the likelihood that the next generation’s initiatives will be more effective than those launched by our “straight-line causality”-inspired generation.

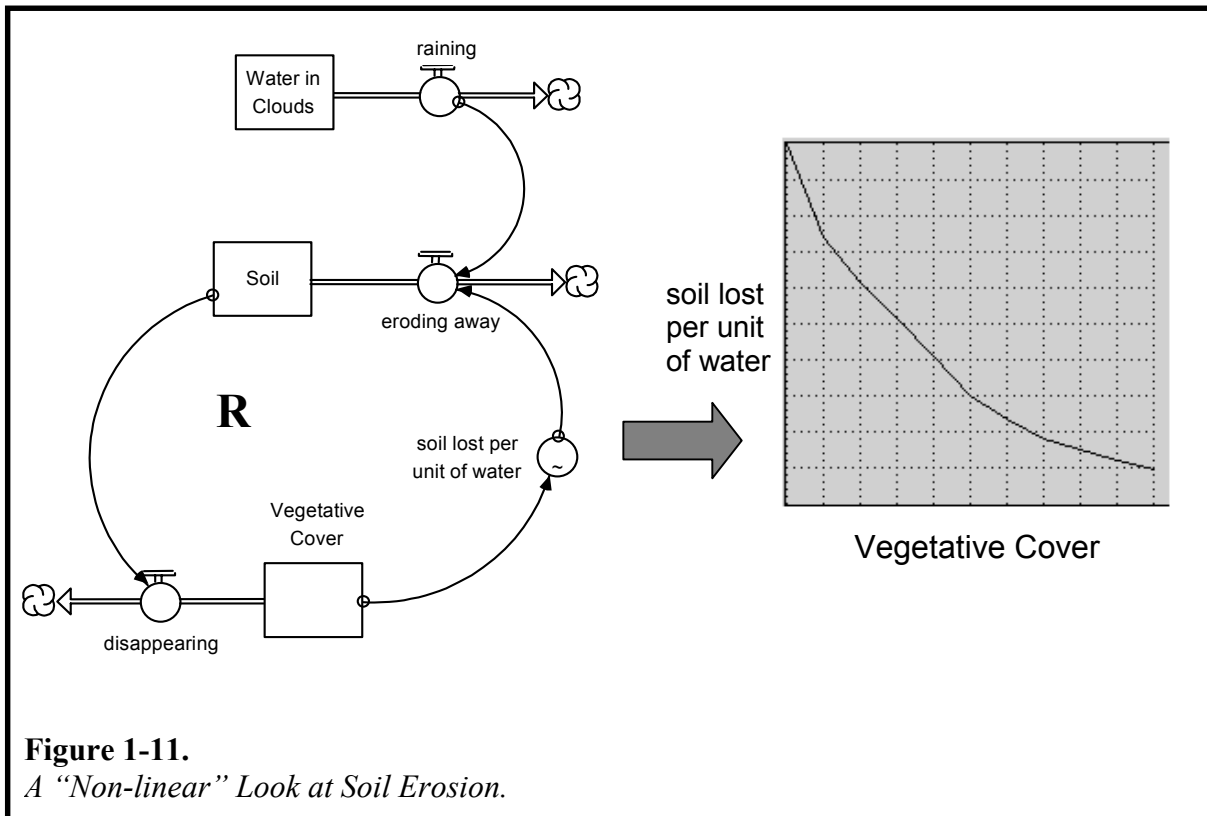
The third and fourth “meta” assumptions implicit in Laundry List Thinking are easy to spot once the notion of feedback loops enters the picture. The causal impacts in Laundry Lists are implicitly assumed to be “linear,” and to unfold “instantaneously” (which is to say, without any significant delay). Let’s examine these two remaining Laundry List “meta” assumptions...

*Non-linear  
Thinking*

The assumption of “linearity” means that each causal factor impacts the “effect” by a fixed, proportional magnitude. In terms of the Universal Soil Loss equation, for example, someone might collect data for a particular ecosystem and then statistically estimate that, say, an 8% increase in rainfall (R) results in a 4% increase in soil loss per unit of area (A). We could then form the following equation to express the relationship:  $A = 0.5R$ . You probably immediately recognized it as your old friend...the equation of a straight line (i.e.,  $Y = mX + b$ ). In a linear equation, a given change in the “X” variable results in a fixed corresponding change in the “Y” variable. The variable expressing the amount of the corresponding change is “m,” the *slope* of the straight line relating the two variables. Let’s contrast the “linear” view of the relationship between rainfall and soil loss, with a “non-linear” view as illustrated in Figure 1-11.

As the wire running from *raining* to *eroding away* shows, erosion is “driven by” rainfall. The equation for *eroding away* is *raining* (an amount of water per time) times *soil lost per unit of water*. Notice the “~” on the face of the variable named *soil lost per unit of water*. It designates the variable as what’s called a “graphical function.” (I will discuss the graphical function in more detail in Chapter 6). The function is drawn as a graph on the right side of Figure 1-11. The

graphical relationship indicates that the amount of soil that flows away with each unit of water is *not* constant! Instead, it depends upon the amount of *Vegetative Cover* that's present at the time. In particular, as the amount of *Vegetative Cover* increases, the quantity of *soil lost per unit of water* decreases—an *inverse* relationship (vegetation sinks roots into the soil that help to hold soil particles together, and in so doing, reduces erosion).



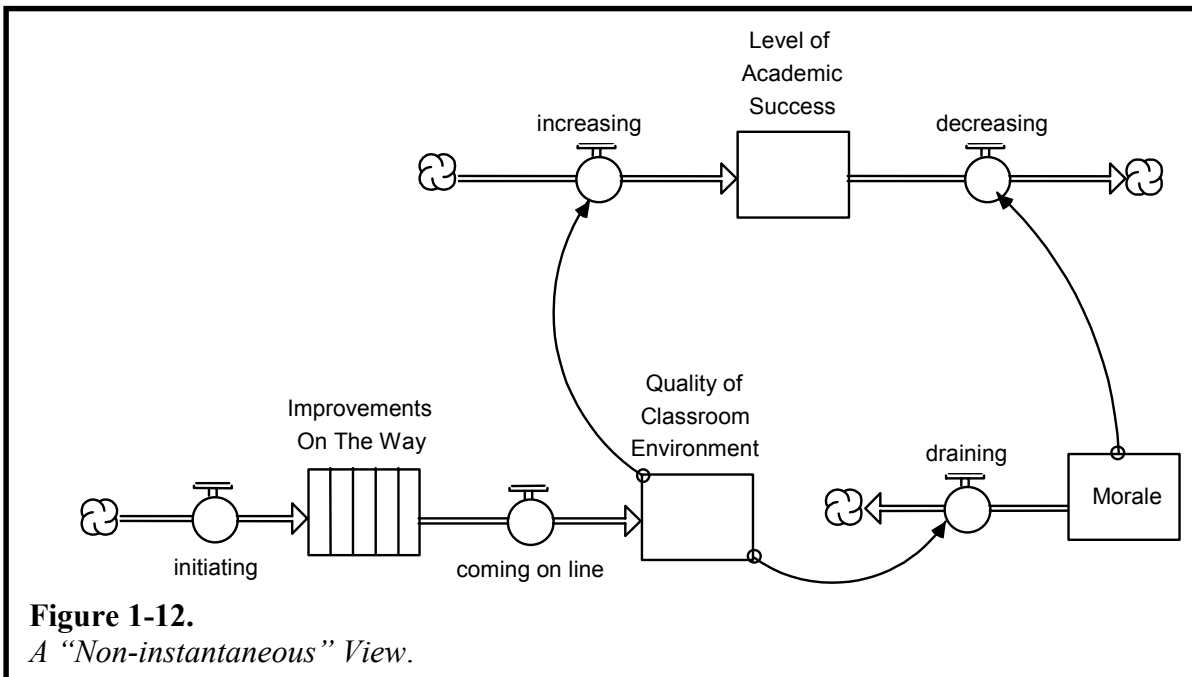
The assumption being made here is that there is *not* a “linear” relationship between rainfall and the amount of soil being carried away by water. Instead, the strength of the relationship will *change* as the magnitude of a third variable, *Vegetative Cover*, changes. And, the plot thickens...As the wire running from *Soil* to *disappearing* (the outflow from *Vegetative Cover*) indicates, the rate at which vegetative cover disappears depends on how much soil is in place. The less soil in place, the more rapidly vegetative cover disappears; the more rapidly vegetative cover disappears, the less of it there is; the less vegetative cover, the more rapidly soil will be lost. A vicious cycle, or *Reinforcing feedback loop* (thus the “R”).

Feedback loops, as they interact with waxing and waning strength, create *non-linear* behavior patterns—patterns that frequently arise in both natural and social systems. Such patterns cannot arise out of simulations of mental models whose relationships are *linear*.

Developing *Non-linear Thinking* skills (the sixth of the Systems Thinking skills) will enable students to construct mental models that *are* capable of generating such patterns. This, in turn, will enable students to better anticipate the impacts of their actions, as well as those of the initiatives that will be implemented to address the pressing social and environmental concerns they will face upon graduation.

The fourth implicit “meta” assumption associated with Laundry List Thinking is that impacts are felt “instantaneously.” For example, when we look at the factors impacting academic success, the implicit assumption is that each exerts its influence “right now.” Take “Good Classroom Environment.” The idea here is that a good classroom environment—i.e., physical factors like space, light, good equipment, etc.—will encourage students to achieve high levels of academic success. Boost the quality of the physical environment...boost academic success. Sounds reasonable, but when you draw a more operational picture, the cause-and-effect is not quite so straightforward. Take a look at Figure 1-12.

Instead of words and arrows—Good Classroom Environment → Academic Success—to show causality, Figure 1-12 depicts the associated causal relationships *operationally*. In particular, the Figure includes the potentially significant *delay* between initiating improvements to a classroom environment and the “arrival” of those improvements. The vehicle for capturing the delay, as you’ve already seen (in Figure 1-3), is called a “Conveyor.” In this illustration, suppose the delay had to do with, say, the delivery, and subsequent bringing on line, of a mobile computer lab for the classroom. Such delays have been known to stretch out for months. In the mean time, it’s possible that student and teacher morale might suffer. This, in turn, could stimulate an *outflow* from the *Level of Academic Success* before the arrival of the new lab has a chance to stimulate the associated inflow!



Delays are an important component of how reality works. Leaving them out when structuring relationships in mental models undermines the reliability of simulation outcomes produced by those models. Building the *Operational Thinking* skills that enable students to know when and how to include delays should be a vital part of any curriculum concerned with development of effective thinking capacities.

#### *A Brief Recap*

Okay, it's been a long journey to this point. Let's briefly recap before resuming. I asserted at the outset that our education system was limiting the development of our students' *thinking, communicating* and *learning* capacities. I have focused thus far primarily on thinking capacities. I have argued that the education system is restricting both the *selecting* and *representing* activities (the two sub-processes that make up *constructing* a mental model). Where restrictions have been identified, I have offered a Systems Thinking skill that can be developed to overcome it. Six Systems Thinking skills have been identified thus far: 10,000 Meter, System as Cause, Dynamic, Operational, Closed-loop and Non-linear Thinking. By developing these skills, students will be better equipped for constructing mental models that are more congruent with reality. This, by itself, will result in more reliable mental simulations and drawing better conclusions. But we can do even more!

We're now ready to examine the second component of thinking, *simulating*. Let's see what's being done to limit development of

**Thinking:  
Simulating a  
Mental Model**

students' capabilities in this arena, and what we might do to help remedy the situation.

The first component of thinking is *constructing* mental models. The second component is *simulating* these models. Throughout the discussion thus far, I've been assuming that all simulating is being performed *mentally*. This is a good assumption because the vast majority is performed mentally. How good do you think you are at mental simulation? Here's a test for you...

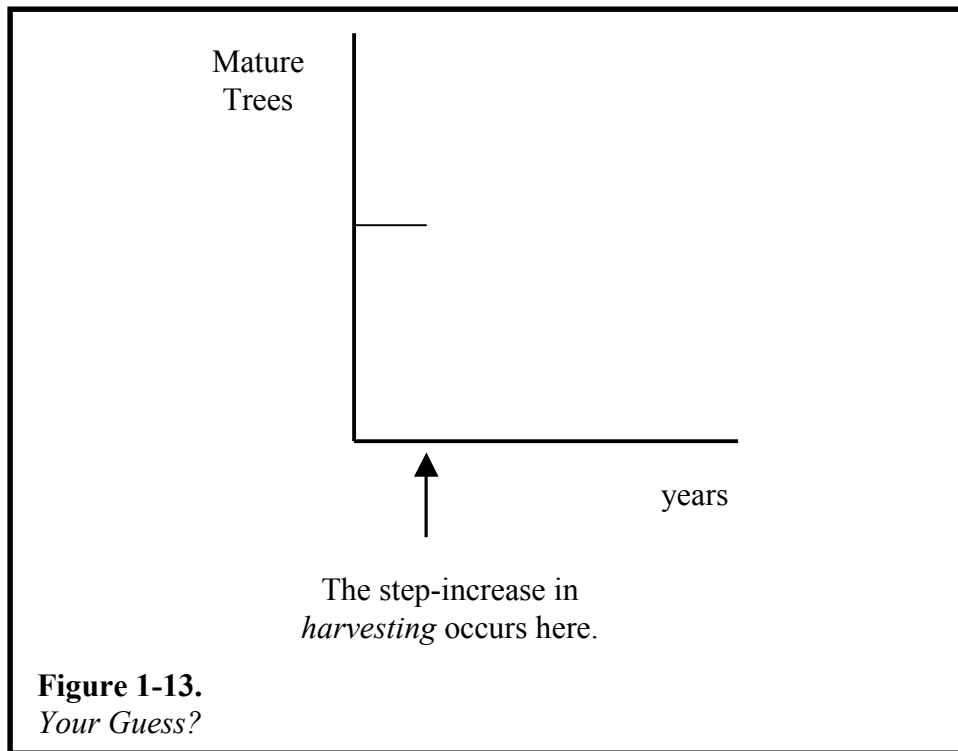
Read the passage that follows and then perform the requested mental simulation ...

A firm managing a certain forestland is charged with maintaining a stable stock of mature trees, while doing some harvesting of trees each year for sale. Each year for the last 50 years or so, the firm has harvested a constant number of mature trees. In order to maintain the stock of mature trees at the specified target level, the firm follows a policy of re-planting a seedling for each mature tree it harvests in a given year. In this magically ideal forest preserve, no animals eat seedlings, and *every* seedling that is planted not only survives, but grows to maturity in *exactly* six years. Because the preserve has been operating in this manner for more than 50 years, it is in "steady-state." This means that an equal (and constant) number of trees is being harvested each year, an equal number of seedlings is being planted each year, and that same number of trees is also maturing each year. The stock of mature trees has therefore remained at a constant magnitude for 50 years.

Now, suppose that this year the firm decides to step up the harvesting of mature trees to a new, higher rate, and to then hold it constant at this rate for the foreseeable future.

Mental simulation challenge: *If the firm continues with its current re-planting policy (i.e., re-plant one seedling for each mature tree that it harvests), and ideal conditions for seedlings continue to prevail in the preserve, what pattern, over time, will be traced by the magnitude of Mature Trees following the step-increase in the harvesting rate? Sketch your guess on the axis provided in Figure 1-13.*





If you are like 90% of the people to whom we've put a question like this, you sketched an incorrect pattern. If you'd like to check your intuition, open the model named "Trees" in your *Intro to Systems Thinking* folder and run it.

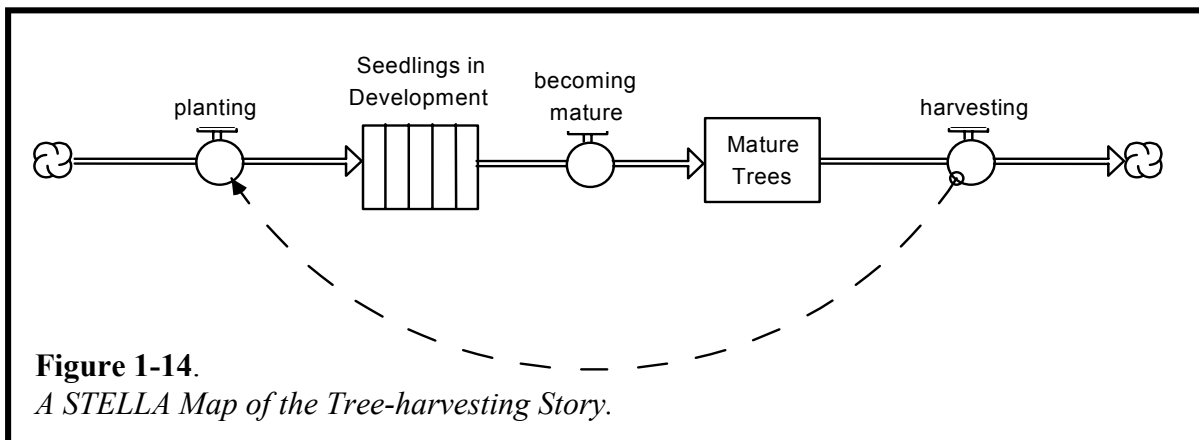
The fact that 90% of the people who take this test guess incorrectly is significant. The percentage holds cross-culturally, and independently of gender, education level, and any other attribute we've looked at. This means the result is saying something about human beings *in general!* It's saying that, as a species, we're not very good at constructing a mental model from a written description, and/or mentally simulating that model once it is constructed. It's worth noting that the system we asked you to model and simulate is very simple! It's a whole lot simpler, for example, than the one spitting up issues like kids killing kids, drug addiction, and global warming. And we're simulating this latter system in our heads in order to create policy initiatives for addressing these issues! Scary? You bet!

If you refer back to Figure 1-3, you'll be reminded that *simulating* is a key part of the self-reflective learning loop. Reflecting on the simulation outcomes we generate is an important stimulator of change in our mental models. But what if those outcomes are bogus? What if we are not correctly tracing through the dynamics that are implied by the assumptions in our mental models? That's right...The *Self-reflective* learning loop will break down. In addition, because simulation outcomes are one of the raw materials being made available

for scrutiny by others in the communicating process, a key component of the *Other-inspired* loop will break down, as well. So, it's very important that our simulation results be reliable in order that the associated learning channel can be effective.

Detailing the reasons for our shortcomings (as a species) in the simulation sphere is beyond the scope of this Chapter. However, part of the issue here is certainly biological. Our brains simply have not yet evolved to the point where we can reliably juggle the interplay of lots of variables in our heads. There is, however, growing evidence to suggest that people can hone this capacity. But in the current education system, there is very little attention being paid to this vital skill.

Systems Thinking can offer a couple of things that can help in this arena. The first is the language of stocks and flows. Because the language is both visual, and operational, it facilitates mental simulation. As an illustration, look at Figure 1-14. It's a *STELLA* map developed from the tree-harvesting story. Let's use it to facilitate a mental simulation.



**Figure 1-14.**  
*A STELLA Map of the Tree-harvesting Story.*

As described in the written passage, the system begins in steady-state. This state is easy to visualize using the map. It means that the two stocks are constant, because the three flows are equal (and also constant). The *harvesting* flow then steps-up to a new, higher level and remains there. Given this pattern for the outflow from *Mature Trees*, the map “tells you” that the pattern over time traced by the stock will be completely determined by what happens to the *becoming mature* flow. Do you “hear” this?

If the *becoming mature* flow steps-up at the same time as the *harvesting* flow, the *Mature Trees* stock will remain unchanged; i.e., inflow and outflow will remain equal. Hence, the magnitude of the

stock will not change. But does the *becoming mature* flow step up at the same time as the *harvesting* flow?

No! For six years after the step-increase in *harvesting* occurs, the *becoming mature* flow will remain equal to the pre-step *harvesting* rate. That's because there is six year's worth of seedlings that are "in development," and the number of seedlings in each year's cohort is equal to the value of the pre-step *harvesting* rate. So, six years *after* the step increase in *harvesting* occurs, the *becoming mature* flow will finally step-up to equal the new, higher volume of *harvesting*. At this point, the system will be back in steady-state. However, because the *becoming mature* flow volume was less than the *harvesting* volume for six years, the stock of *Mature Trees* will have declined for six years. And because *becoming mature* was less than *harvesting* by a constant amount, the decline will be *linear*. The *Mature Trees* stock will now rest at a *permanently lower* level than existed prior to the step-increase in *harvesting*.

*Scientific  
Thinking*

*STELLA* maps really do facilitate mental simulation! But the other nice thing about them is that they are readily convertible into models that can be simulated by a computer. And if you follow "good practice" in doing your *STELLA* simulations, they will serve as an excellent "sanity-check" on your mental simulation. Think of the software as a fitness center for strengthening mental simulation "muscles." In order to take full advantage of the exercise facility, it's important to acquire the habit of making explicit a guess about what dynamics a particular model will generate *before* actually using *STELLA* to generate them. Experience has shown that it is far too easy to "back rationalize" that you "really knew" the model was going to produce that pattern. It's also important to put your models into steady-state (at least initially), and to test them using "idealized test inputs" (like STEP and PULSE functions). The collection of rigorous simulation practices are called *Scientific Thinking*, the seventh of the Systems Thinking skills.

*Thinking,  
In Summary*

Currently, in the formal education system, very little attention is paid to developing simulation skills. This means that a very important set of feedback loops for improving the quality of mental models is essentially being ignored. The *STELLA* software is a readily available tool that can play an important role in helping to develop these skills.

**Communicating**

The next process in the Thinking/Communicating/Learning system is *Communicating*. The kind of communicating I'm talking about here is not restricted to what one usually learns in an English composition class. The communicating I'm talking about must become a vital part of *every* class! It's the feedback students provide after scrutinizing each other's mental models and associated simulation outcomes (refer to Figure 1-3).

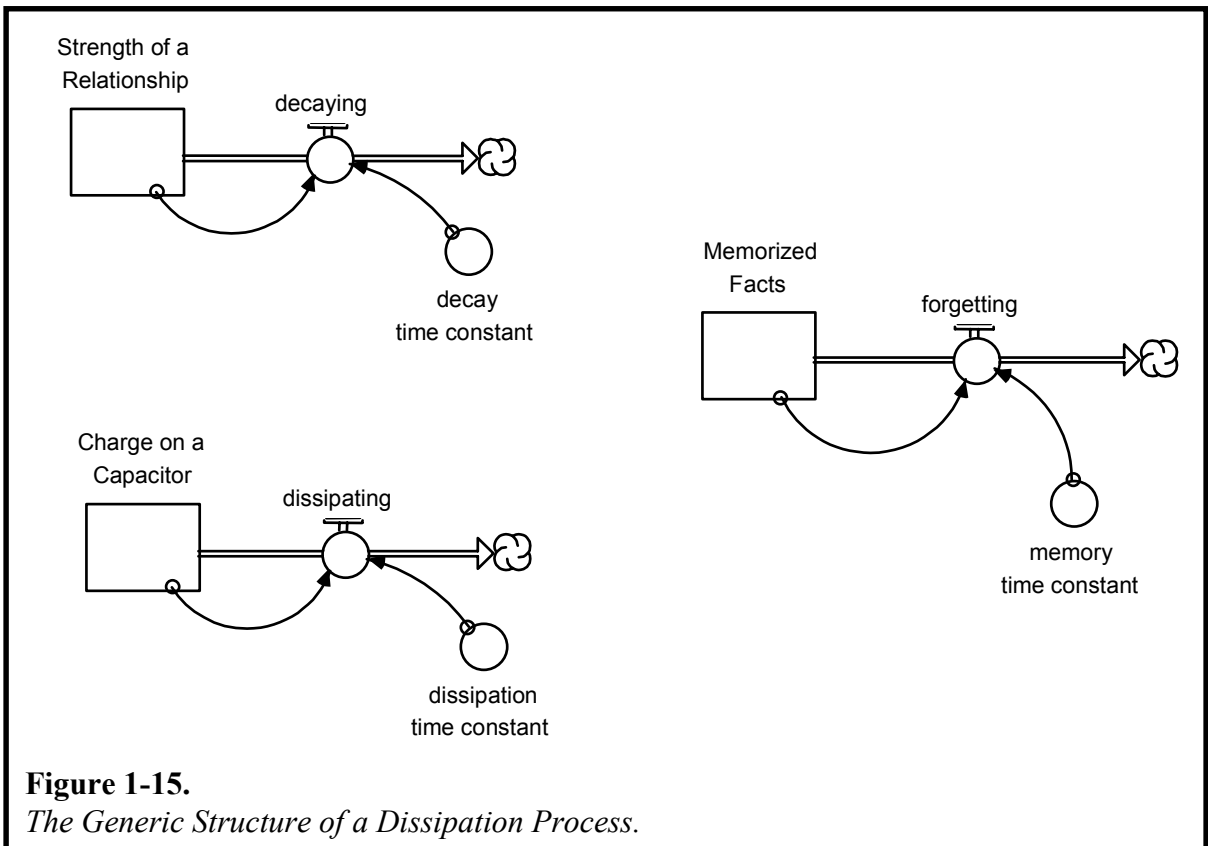
*Empathic  
Thinking*

The current formal education system provides few opportunities for students to share their mental models and associated simulation outcomes. Well-run discussion classes do this (and that's why students like these classes so much!). Students sometimes are asked to critique each other's writing, or oral presentations, but most often this feedback is grammatical or stylistic in nature.

The capacity for both giving and receiving feedback on mental models is vital to develop if we want to get better at bootstrapping each other's learning! Many skills are involved in boosting this capacity, including listening, articulating, and, in particular, *empathizing* capabilities. Wanting to empathize increases efforts to both listen and articulate clearly. Being able to empathize is a skill that can be developed—and is in some ways, the ultimate Systems Thinking skill because it leads to extending the boundary of true caring beyond self (a skill almost everyone could use more of). By continually stretching the horizontal perspective, Systems Thinking works covertly to chip away at the narrow self-boundaries that keep people from more freely empathizing.

But even with heightened empathic skills, we need a language that permits effective across-boundary conversations in order for communication to get very far. And this is where the issue of a content-focused curriculum resurfaces as a limiting factor. Even if time were made available in the curriculum for providing student-to-student feedback on mental models, and empathy were present in sufficient quantity, disciplinary segmentation would undermine the communication process. Each discipline has its own vocabulary, and in some cases, even its own set of symbols. This makes it difficult for many students to master all of the dialects (not to mention the associated content!) well enough to feel confident in, and comfortable with, sharing their reflections. The stock/flow *Esperanto* associated with Systems Thinking can play an important role in raising students' level of both comfort and confidence in moving more freely across disciplinary boundaries.

Figure 1-15 illustrates this notion...



**Figure 1-15.**  
*The Generic Structure of a Dissipation Process.*

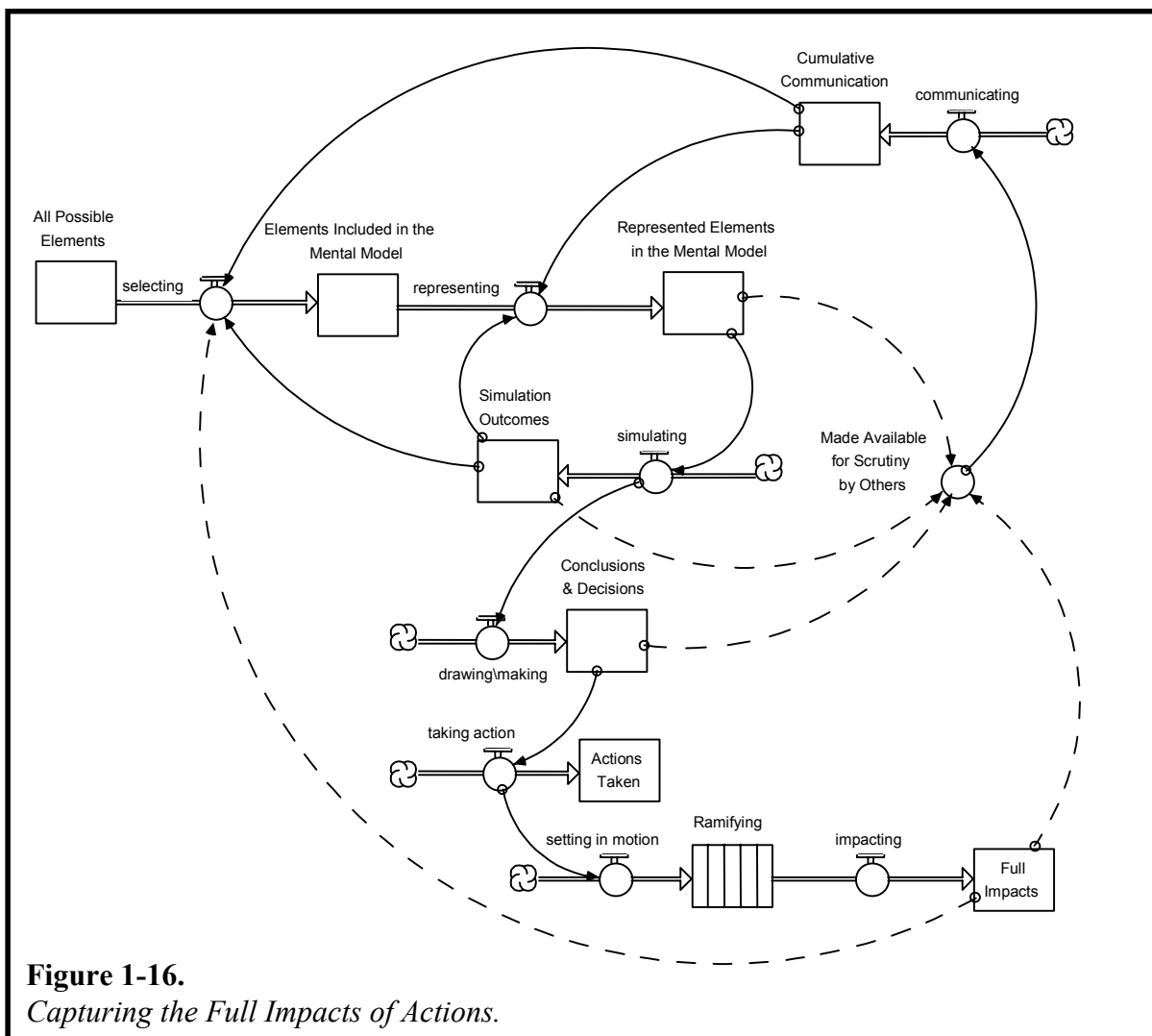
The Figure shows the accumulation of strength in a personal relationship, the accumulation of electrostatic charge on a capacitor, and the accumulation of facts in human memory. Each is represented by the *same* symbol. As stocks, each performs an analogous function—albeit in quite different contexts—which is to “report” the status of a condition. In addition, as illustrated in the Figure, the “logic” by which one or more of the associated flows operate is *generic*. This is, at the very least, a comforting discovery in a world generally perceived to be growing more complex and unfathomable on a daily basis, and in a curriculum rife with detail-dense, dialect-specific content bins. But it also holds the wonderful potential for creating cross-curricular learning synergies. What’s being learned in physics could actually *accelerate* (rather than impede) learning in literature or psychology (and vice versa)! And, by building their capacity for seeing “generic structures,” students will be simultaneously boosting their capacity for making “horizontal” connections in the real world.

Teaching the stock/flow *Esperanto*, and the *Operational and Empathic Thinking* skills needed to “speak/write it” effectively, can go a long way toward improving the student communication capacities needed to realize the synergies latent within a multi-discipline curriculum.

## Learning

Chapters 2-9 of this Guide should provide the nucleus of what's required to deliver this instruction.

Learning is both literally and figuratively the “bottom line” of the thinking/communicating/learning triumvirate. Because the three processes are intimately intertwined, all of the Systems Thinking and *STELLA*-based suggestions that have been made for improving the *thinking* and *communicating* processes would also work to improve the *learning* process. There is one more suggestion I would like to make that focuses more exclusively on the learning process itself. I'll enlist the *STELLA* software to paint what I hope will be a clear picture of the suggestion. The picture appears as Figure 1-16.



**Figure 1-16.**  
*Capturing the Full Impacts of Actions.*

In processing the Figure, you may wish to take a look back at Figure 1-3. It differs from Figure 1-16 in only one way. The two learning-generation links, which emanated from *Ramifying* in Figure 1-3, now come off *Full Impacts*. This implies that somehow we've been able to

“close the learning loop” on the full ramification of actions that have been taken, rather than capturing only the partial impacts (because those impacts were still ramifying). How might we be able to achieve this?

The answer I’d like to propose falls under the rubric of what’s known as “organizational learning.” This is a term, tossed about with abandon, which has been deeply enshrouded in fog since it was first coined. To borrow a phrase...Organizations don’t learn, *people* do! I use the term “organizational learning” to refer to *learning that is captured, and then somehow stored, outside the bodies of the individuals who create and make use of it.* As such, when individuals disappear, their contribution to the collective understanding does not go with them. And, when new people arrive, they are able to quickly come up to the current collective level of understanding because that understanding is housed in some extra-corporal reservoir.

The vehicle I would propose for creating this “extra corporal” reservoir—call it an “organizational learning infrastructure”—is a set of *STELLA* models. The infrastructure would work as follows...Each model would be used to predict what will occur (not in a numerically precise way, but in a qualitative sense) in whatever context it is serving. A process would be in place to monitor actual outcomes versus model-generated predictions. When discrepancies between the two arise, the assumptions in the model would be scrutinized, discussed, and then adjusted accordingly. Over time, the model would continuously improve as a representation of the reality about which learning is being accumulated.

It would be great to implement this sort of “extra corporal” learning process in a classroom over a school year, perhaps even extending it to multiple years—and thereby giving students some sense of learning continuity as they progress through grade levels. Having developed experience with such a process while in school may inspire some students to continue the much-needed practice of seeking to harvest the learning from “full impacts” in their professional and public service careers.

## **In Summary**

The challenges today’s students will face when they leave school are formidable, and growing more so every day. The education system has not evolved its curriculum, methods, and tools so as to better equip students for addressing these issues. The system continues to be driven by a “content acquisition” standard that features *memorization* as its primary “learning” activity. The key to evolving our education system lies in tapping the potential synergies that exist in the mutually-reinforcing processes of *thinking, communicating* and *learning*. Systems Thinking and the *STELLA* software can bring a lot to this party!

## What's to Come

This Chapter identified eight Systems Thinking skills that leverage all three processes. Each skill can be readily implemented into today's school systems. The primary barrier to doing so is the view that the mission of an education system is to fill students' heads with knowledge. This view leads to sharp disciplinary segmentation and to student performance rubrics based on discipline-specific knowledge recall. Changing viewpoints—especially when they are supported by a measurement system and an ocean of teaching material—is an extremely challenging endeavor. But the implications of not doing so are untenable. The time is now.

The remainder of the Guide relies on an extended analogy. Learning to use the *STELLA* software to render mental models is treated as analogous to learning to write an expository composition, such as a short story or screenplay. The Guide is divided into two parts.

Part 1 is entitled **The Language of Systems Thinking: Operational, Closed-loop, and Non-linear Thinking**. The six chapters in this Part form a parallel progression of language/grammar and the associated thinking skills needed to apply that language and grammar effectively. You'll build up from parts of speech to short story themes, and in the process begin to internalize the first three of the eight Systems Thinking skills.

Part 2 of the Guide is entitled **The Writing Process: 10,000 Meter, System as Cause, Dynamic, Scientific and Empathic Thinking**. In the three chapters in this Part, you'll learn good "writing" practices, walk through an illustration of these practices, and finally be given some general "writing" guidelines.

As you've probably concluded if you've endured to this point, this isn't your typical "User's Manual." That's because learning how to make effective use of the *STELLA* software really has little to do with the mechanics of the software itself. The software's user interface is simple enough to master just by "playing around" for a few hours. The real issue with the *STELLA* software is internalizing the associated Systems Thinking skills, as well as the language and method. This is conceptual, not mechanical, work! The Guide is concerned with helping you to make a shift of mind, and to internalize a new language. If you need technical assistance in learning to use the software, there are excellent *Online Help Files* and self-study tutorials that accompany your software. For conceptual help, visit the HPS website ([www.hps-inc.com](http://www.hps-inc.com)) for articles and references to Systems Thinking resources.

Congratulations on your purchase of the *STELLA* software, and good luck in your efforts to apply it. The benefits you'll reap from learning Systems Thinking will re-pay many times over the investment you will make!