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WRITING AND MODELING: USING A NOTEBOOK TO LEARN ABOUT SYSTEM DYNAMICS

by Timothy Joy

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The happy alignment of storytelling and mathematics

Computers are often being used for what the computer does poorly and the human mind does well. At the same time the human mind is being used for what the human mind does poorly and the computer does well.
—Jay Forrester,"Counterintuitive Behavior of Social Systems," 1971

Of all the unintended consequences of system dynamics instruction, this surprising alliance of storytelling and mathematics quickens the poetic impulse of this erstwhile math teacher disguised for 17 years as an English teacher. Years of dark frustration with grammar and stodgy literature instruction peel and curl away—here is the power of two disparate disciplines sharpened by each other, angled to cleave an idea.

At its simplest, students merely draw behavior-over-time graphs (reference behaviors) and, beneath them, compose a brief story which might tell of real events described in that line, *but make no reference to the mechanics of the graph or a model.*

When the game started, I was excited to play but then I got hit hard. It took a while to recover. Even though I got hit again, I was able to get back on my feet and played well. Late in the game, though, after a few close calls, I was drilled off tackle and laid out for a bit. I didn't want to get up and was glad to get out of the game. No way was I going back in.

As students gain proficiency, complicate the y-axis: not just a single variable such as houses built, but something relative to something else such as the fraction of houses to apartments built over some length of time. Another worthy exercise goes a step past simple behavior-over-time graphs. Students plumb dynamics more deeply, for instance, when they can step away from time and use a graph to represent one change relative to another *regardless* of time: the amount of guilt Pip acquires as he learns of his benefactor's efforts, or the effect of a declining food supply on a population's death rate. Such graphs *can* be used in the STELLA[2] software and are known as "graphical converters."

Such complication in a graph, just as in storytelling, provides richness and breadth readers covet. Using words to describe the points on a fluctuating line within well-defined axes helps students understand that a given number has a meaning; numbers need not be abstract, but have real construct in the world they inhabit. Let me repeat that. *Students will understand that numbers have a real construct in their world.*

A word of caution is warranted here: using graphs in these ways opens a world of variability that arises from a hierarchy of specific graphical uses, such as multipliers, within a system dynamics model. From readily accessible reference

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BARRY RICHMOND SCHOLARSHIP

Pegasus Communications Inc (www.pegasuscom.com) has generously donated a free registration to their annual Systems Thinking in Action conference to a K-12 educator in the form of The Barry Richmond Scholarship.

Process:

Each year the Director of the Creative Learning Exchange, in consultation with educators familiar with the introduction of systems thinking into K-12 education, will nominate one person who exemplifies Barry's drive to create "systems citizens" in her or his efforts in K-12 education.

The process used to decide will be an informal gathering of information and consensus rather than a formal process of application or nomination to the CLE. If, at any point, there is a need to further formalize the process, the CLE will, in conjunction with Pegasus Communications, do so.

2003 Nomination

Davida Fox Melanson

Davida Fox-Melanson is the Superintendent of Schools in Carlisle, Massachusetts. Through her leadership over the last decade, she has consistently nurtured the growth of system dynamics and systems thinking throughout the curriculum and organization of the schools because she ardently believes that students will need these skills and this perspective to thrive in a dynamically complex world.

Maintaining a clear focus on this goal, Davida has fostered a culture of continuous improvement, marshaled financial resources, provided training opportunities and on-going support, heralded student and staff accomplishments, and diplomatically countered resistance to change. System dynamics and systems thinking are becoming a part of the school's shared vision and culture.

This year, to raise the bar and include all teachers, Davida has required at least one systems lesson a year for each teacher's performance evaluation. Framing each decision in terms of "what's best for the kids," Davida takes seriously her responsibility to prepare her students for their future.

EDITORIAL

As the school year starts with the enthusiasm engendered by the newness of different students, different courses and new challenges, think about how you and those around you can more effectively use systems thinking and dynamic modeling in your classroom, school, and district. Think about what you have done, and contemplate telling others about it at the ST & DM conference in June 2004. Think about what you want to do, and do it early enough so you have time to refine it this year. Think about how to use a simple BOTG, stock/flow map or causal loop to get a point across to your students, other teachers, or administrators. Do it several times and then share it in June.

I hope you all can—as we try to here at the CLE—use the impetus of the conference to contemplate what you are doing using SD this year and how to do it more effectively—and to have fun doing it! May this be a productive year for you, productive in students and teachers enhancing, or regaining, their love for learning.

Take care,

Lees (stuntzln@clexchange.org)

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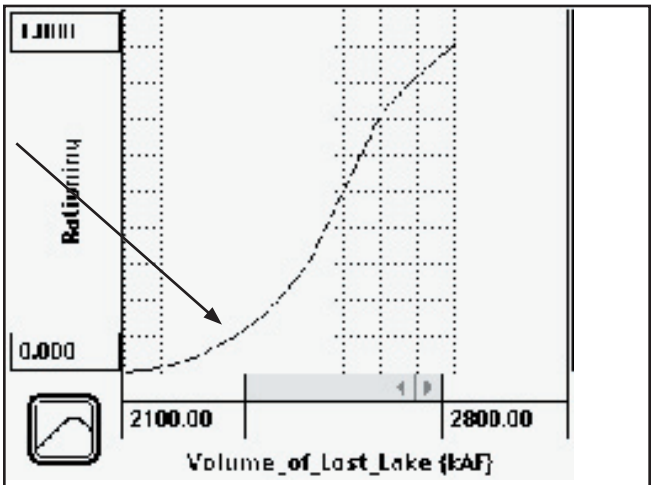
behaviors to the more demanding graphical converters, each use provides a richer story component for the modeler to draw on. (See Leslie Martin's *Mistakes and Misunderstandings: Table Functions* for more on this topic[3].) This capacity for deep learning is especially true when students draw portions of a model and the details of a graphical converter within that model section. Their assignment was to study the converter's workings and determine how it impacts the feedback of that model section. Then, tell a story that details the curve of the line and how its *shape* redounds throughout the model.



The rationing converter, on the other hand, is my idea. The part different from others is mostly the 0.0 – 1.0 rationing, which converts to 0% to 100% of the amount that each person would use each year through another converter (*water wanted*). The rationing is stricter as the volume of the lake dwindles. This makes the whole model more realistic since it would be negligent to let the lake dwindle to zero, eventually, over a period of 150 years.

A student sample gives a clearer picture: this student's work demonstrates how he is thinking through the idea of the graph. Even though he alludes to both the model lake and the actual lake, he is at a dialectic stage wherein the one informs the understanding of the other.

As Huck Finn might say, this is powerful hard to do. But it is also exquisitely useful. Each model construction is, in fact, a rhetorical position, an ancient idea that folks like Aristotle, Cicero, and Coleridge would advise on. Students discover they cannot write accurately and effectively without a sound understanding of the feedback, nor can they trace the model feature terribly well without having appropriate and consistent language. The more fluent students become at telling the story, the more facile they are at building the model.

Notebook topics and activities

The world is so full of a number of things,
I'm sure we should all be as happy as kings.
Robert Louis Stevenson

As students work through these topics and activities, please keep ever in your mind—and in theirs—that *engaged reflection* is critical to understanding. Make sure that students will have some time to synthesize their thoughts, bundle them up and place them alongside some thoughts they already know. This debriefing is absolutely critical. Otherwise, these activities will yield little more than a worksheet.

1. **Identify key STOCKS** you have witnessed today—beginning from the time you woke up until the time you walked into this room. Students ought to list as many as possible, but certainly no less than ten. You will note that students are likely to recognize and report only *physical* stocks, such as cars, students, boxes of cereal, water in puddles; therefore, be certain to give some time over to listing *non-physical* stocks such as trust, worry, boredom, frustration. As a closing activity, ask students to chose one or two (or more) stocks and add *unit-consistent* flows to them. Sharing a few of these with the whole class would complete a very commendable warm up activity.

2. **Identify key FLOWS** you have witnessed today—beginning from the time you woke up until the time you walked into the classroom. Just as with the stock exercise, students ought to list as many as possible, keeping in mind to label each flow with an "-ing" ending. Likewise, once the list reaches some satisfactory level (say, ten), students should begin to imagine what stock is being filled or emptied by these flows. As a challenge item, it may be worthwhile to ask students if any two or three flows on their list are related; ask how they are related; ask if one flow *depends on* or is *influenced by* another flow. Can anyone close a loop? Tell the story.

3. **Start with a FLOW drawn and listed on the board**, something fairly common, such as *driving*, or *reading*, or *eating*, or *raining*. Ask students to connect this flow to a stock that is filled or emptied by this flow. Next, students might ask, as the stock is filled or emptied, what other related *flow* might be directly accelerated or diminished by this chang-

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ing stock. As a check for both narrative and modeling accuracy, ask students to name the units in each connected stock and flow strand (they should be the same). Starting with a common flow experience takes students into their personal experience, something they intuitively know but do not readily scrutinize. This is an excellent practice—to see system connections in their personal lives.

4. **Start with a STOCK drawn and listed on the board**, stocks one might find in the classroom or in a student's common experience, such as *Books, Garbage, Clothes, Teachers, Homework,* or *Amount of Reading*. Ask students to identify the flows that fill and empty these stocks. Further, ask students to identify influences that *speed up* or *slow down* the changes in these stocks. How might these influences be included in a map? Can students draw a closed loop from one stock to another?

5. **Use some strategies from the *Systems Thinking Playbook*[4]**, such as the Paper Fold sequence, a set of steps to walk students through "half-times," a particularly difficult concept to understand because it involves two concepts *at once*—volume and time. Additionally, the Paper Fold sequence can also be used to describe exponential growth. While the *area* is "halving," the *thickness* is doubling. This is a lovely thing for students to contemplate. Drawing out the graph that depicts the paper fold is very helpful. You might depict a stock and flow diagram of the exercise. You might also simply write out the doubling sequence through a 10th doubling; sometimes, the neuromuscular connection will help seal the understanding. Some questions worth considering here: where might we see this phenomenon in the world? In school? In our lives?

6. **Consider long and short patterns**. Ask students to draw two graphs: one of a short pattern—say, one that recurs in a year or less, such as rainfall, and one of a long pattern—say, one that recurs over a decade or a century, such as growth of dam building. Students may need some examples to get them rolling. For instance, each year we undergo seasonal changes; over decades and centuries, we also undergo climatic shifts. Students flow into and out of hallways every period of the day; school populations shift from generation to generation. Long and short patterns need not be related to be useful thoughts: the use of pesticides on farmland has an ebb and flow to it; so, too, does the volcanic activity under the Cascade Range. Asking students to gather a series of long and short patterns, to *note what is similar in both* and compose some thoughts about these connected patterns is crucial. Ask students to note how human activity *changes* or *is changed by* some of these patterns.

7. **Respond to a specific systems question or statement**. Ask students to respond with both a map or graph and a narrative that describes their position or understanding:
   a. Limits cause a shift in loop dominance. Why so, and why is this a concern?
   b. We need to decide the kind of world we'd like to live in, or the system will decide it for us.
   c. The key to the *attractiveness principle* is that people must choose the level of <u>*un*</u>attractiveness they're willing to live with.
   d. The source of a system problem is often distant in time and space.
   e. There is no *away* into which we throw things.

   There are many more of these available from a number of sources.

8. **Ask students to read an article** from a newspaper or magazine that strikes them as a systems issue—these might include references to change over time, shifts in human population, shifts in the natural world, or unexpected things happening as a result of a policy. Usually, students will find these articles contain references to things changing over a long period of time, say, at least ten years. It is good for students to allow *two notebook pages* for this assignment:
   a. Supply a copy of the article.
   b. Write a brief summary (~ a paragraph).
   c. Draw a behavior-over-time graph, providing a caption sufficient to tell the story of the line the student drew.
   d. Identify key STOCKS and FLOWS, and draw a preliminary map.
   e. Identify the feedback that is either *described* or *omitted*; to the extent students are able, identify the feedback as either <u>reinforcing</u> or <u>balancing</u>.

This particular assignment can have considerable impact on students and can effectively engage students for whole class periods. Do not shy away from this possibility, since their building and grappling with *real systems* is what engenders understanding. (See work by Diana Fisher[5] on this.)

9. **Ask students to share their newspaper reading**. A student provides everyone with a copy of the article she read, draws her map on the board, and tells of her understanding of the story. All students glue the copied story in their notebook, draw the map, and then discussion follows. Often, there are amended maps, comments that connect this current story with something we have studied or considered earlier. Doing this on a weekly basis, allowing a different student to share each time, ensures that all students will have double-pages of stories and stock/flow diagrams throughout their book.

10. **Use the "Story of the Month"** from the High Performance Systems web site (www.hps-inc.com) as a starting point for mapping. For instance, in Fall 2001 HPS published a series of small models to think about terrorism; specifically, the models helped people think about the unintended consequences of the war in Afghanistan and how the U.S. bombing campaign might *increase* the number of terrorists rather than reduce them. Draw the map on the board, telling the story as the map unfolds, and discussion will follow. Students will need to capture this map in their notebook, and may have to turn their notebook sideways to allow it. With each discussed point, *add to the map*. With each addition, ask students to compose a one or two sentence narrative that details how the new piece adds to and enlarges the story. At some point, the discussion will reach saturation—you will run out of room on the chalkboard.

    Once this happens, go to a next step: as a class, begin to identify *the closed loops* in the system, using a different color chalk, and ask students to "tell the loop story." This process of identifying the closed loops is among the most important things you can do as a systems teacher—*recognizing closed loops is the most incisive work our students do.*

11. **Identify a series of related STOCKS** by simply listing them on the board: *students, classrooms, teachers, books,* and *homework*. You may want to list more, but you might choose a topical list from the news or recent events in school. Whatever the case, ensure the list has some gritty meaning for students. Ask students to compose a brief story/diagram that links two or three or four or more of these stocks; that is, students will need to imagine the connections among the stocks, and fill in the appropriate FLOWS and CONNECTORS that make the connections plain. (I typically tell students to avoid converters in this exercise, as they will unnecessarily complicate the map.) This practice of *deriving closed loops* from a related list is a first step toward ultimately doing the same thing with an ostensibly unrelated list. A few imaginative maps on the board and the discussion is off and running. As usual, I ask students to draw the other maps in their own notebooks.

12. **Draw maps** with graphs of some significant timeline. For instance, draw a map of a local watershed that also includes graphs of population change, road building, annual water cycle, and home construction. These data tell a critical, dynamic story and can launch some fascinating discussions about key stocks, about growth, limits, trends.

13. **Set up a special section for glossary of terms**. The quickest method is simply for students to indicate a special section by folding over a page diagonally, probably for the last ten pages or so. It may be possible to set up quasi-alphabetical listing of terms, or you may simply allow students to list terms as they come up in class. (Recently, I have taken to placing boxes around key terms on the chalkboard as they emerge in discussions, and students also do this so the words/phrases can be readily found in context. That these words/phrases also match the defined terms in the glossary is a plus.) Another possibility is that you provide a list of key systems terms typed out and students can glue them in the notebook.

14. **Follow-up questions** to experiments and observations. After a class experiment with, for example, the Pharmokinetic Lab developed by SimHealth at Oregon Health Sciences University[6], student discussion is typically lively and their observations can fill a board

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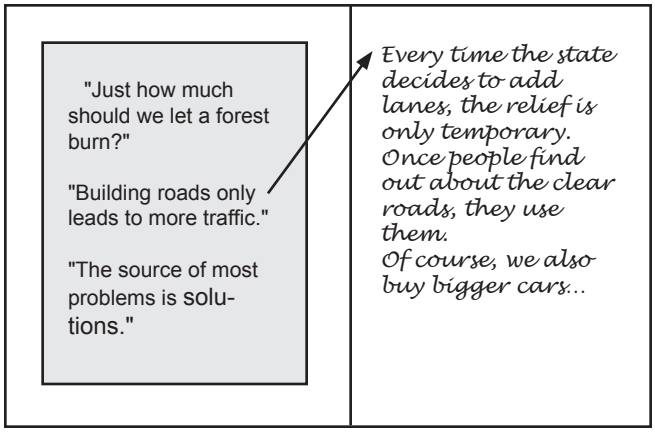
(or two). Other times, student discussion may take us down an interesting road based on any of the previously mentioned methods. A thoughtful follow-up is to extract one or two highly charged statements or provocative questions, type them out with sufficient space, make necessary copies, and ask students to glue them into the book, thus:



Students can *choose* which statement or question they are interested in and write a response about a page long. This method is called the *dialectic*, as the student is engaged in a dialogue about an idea. It could be that students will find some synthesizing idea in a grouping of statements. The more connections, the better. This is a superb way to open a session since students are compelled to compose their thoughts before they open their mouths.

By no means is this only the province of high school. This may be most beneficial for the middle school students, allowing them time and some structure to put together ideas. It will help all thinkers see relationships.

15. **Ask students to look back and do an occasional review** of the last two weeks or so. Essentially, students would establish a new page, labeled "Review" and compile "lessons-learned bullets" over a key period of instruction or observation or inquiry. Some students might compile, for instance, a list of crucial questions or critical insights, or key knowledge, or synthesizing ideas that connect these new insights to prior learning. The metacognitive benefits of this approach are significant since the reinforcement of learning, admitting to themselves (and, thereby, *committing*) that they learned it, really does drive the message deep into neural folds.

16. **Writing stories and scenarios** ought to be a more regular feature of what we do. Using regular language to compose the loop stories, and the more complicated multiple-loop stories of a short story writer, will clearly benefit systems learners as they grapple with the long-run implications for, say, traffic on their neighborhood streets if gasoline prices rise too fast or remain at their current levels. A fairly simple story all students can tell is to describe their neighborhood as if we were walking through it just as it is now; then, tell a second story of what it might look like 20 years from now if water uses were restricted due to droughts; further, tell a third story of what it might look like 20 years from now if water were *not* restricted at all. In each case, the writer must imagine the implications of 20 years of feedback, but in a very personal way.

    This is especially excruciating but *very* instructive to excellent math students who seem to intuitively understand dynamics and modeling, but struggle with the basic rhetorical requirements of explaining systemic change.

17. **Use warm-ups repeatedly**, such as the "Just Right" stories, as starting points. See the section before this for a series of examples and some basic methods for using them. The only cautionary note is that even these stories can swallow hunks of time. Therefore, do not burden yourself or the class with capturing a full model all the time; being able to note the stocks and flows and perhaps a simple feedback connection is sufficient to warm the synapses for class. This nearly "Cliff Note" approach to small stories helps students see the ubiquity of stocks and flows; for instance, you might ask, "What are the key stocks on my person right now, and how are they adjusted?"

18. **There are a number of provocative quotations** that can be useful: those that speak of feedback and those that ignore it. Ask students to tell, first, what they believe the quotation means. Perhaps this sounds trivial, but it is starting point: everyone needs to begin with a common understanding before *any discussion* can proceed. Second, students should state whether they agree with it or not, and then state their case. This second piece, obviously, is also critical: how is a student's thinking connected to things we have studied in class?

Here are a few:

a. "Five percent annual growth will ensure a stable community for the foreseeable future." (Boulder, CO, town councilor)
b. "All things, everywhere, all the time, are controlled by feedback." (J.W. Forrester)
c. "I should be able to build my house anywhere on my property."
d. "Do vaccines do more harm than good?"

All one need do is pay attention to the news, whether at school or city or state or international level, for someone to say something you might use in a class. Collect these statements in your own notebook and use them.

19. **Send students out to collect data**. Presumably, students are collecting data for class use: amount of garbage the school collects and disposes of weekly, the number of students passing a given hallway point at a given time of day, the number of cars entering and leaving the parking lot after school. This provides the teacher a wonderful opportunity to give instruction on data collection: What is reliable? What is valid? How to be accurate? What's the best way to *report* a particular type of data?

20. **Occasionally, students may find themselves conducting an interview** or collecting information over the phone or in a face-to-face conversation. Students should note the name, title/job description, company name of the interviewee, as well as note date, time, and location of the interview. Careful paraphrasing, direct quotations, key references, phone numbers, all types of information and leads should be so noted.

Evaluating what students give you

What ultimately causes a paradigm to change is the accumulation of anomalies—observations that do not fit into and cannot be explained by the prevailing paradigm.
Thomas Kuhn

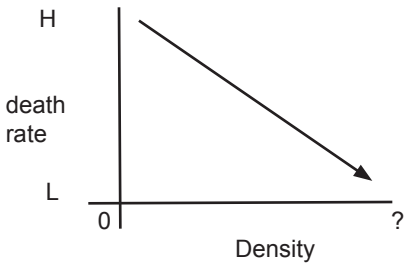
Oh, yeah, right… all your students write something *every day* and you collect it, a stack of notebooks over a foot high, each book crammed with pictures, esoteric diagrams, graphs, criticisms, glued-in news items, compositions, half-baked and abandoned essays, cartoons, dialogues, and mathematical equations. What do you do with all that? With *any* of it? Should you grade it? Comment in it? If you grade it, how do you go about it? Rejoice at their efforts, all of it. Yes. Yes. Rather systematically, of course.

We are all young at this, innocents trundling off to classrooms to try anything and everything, aware enough that we recognize mistakes and then work to mitigate them. So, too, with the efforts of our students—they are intellectually heaving themselves out into one abyss after another; we should celebrate these efforts, what Faith Waters calls "thoughtful courage." This does not mean we ought accept everything willy-nilly; on the contrary, we wish to direct students toward excellence. Using notebooks to pitch an arc toward excellence, then, requires a different touch.

"Grading" is probably not the appropriate term for how one ought to handle this flood of handbooks. I evaluate and comment about every two weeks. Each daily entry, for example, might be worth up to five or ten points (your call), and there might be a finite number of entries, say, ten in a two-week period; thus, some amount earned over 50 (or 100) points. Notebooks that exhibit care for details and legibility, a relative range of speculation and risk, some fullness in explanations and reflection, should receive every point available.

Here's an example that shows a 16 year old working through a problem, scratch outs included.

Relationship of prey density to deaths:
Prey density equals 1: Death rate is what?
High density = fewer deaths
Lower density = more deaths



Death rate is a function of Prey density. Assume linear

So, what is the highest density we have, that is, what can we reasonably expect the highest density to be? Further, when is density a ~~Re~~ non-issue? When do predators stop dying because they are old? This should be in the instructions, unless ~~it~~, density, never matters, which I doubt. For now, assume a max density of 3 predators per sq. mile. Assume a minimum ~~density of~~ death rate of 5%.

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How can one legitimately subtract points?

Because this is a notebook, a place where experimentation, speculation, and creativity are to have free range, do not be stingy at all with points. Indeed, I have never corrected anything in a notebook. *Ever*. It is conversation, a place of generosity and persuasion, a place to model thoughtfulness and diligence. Though one ought to maintain a standard of thoughtful speculation for them to attain, push students to that range by posing questions in their notebooks and, before returning a batch of them, read a few great examples aloud. Over time, this will prove more effective than withholding credit for misguided, though authentic attempts. (Look carefully at the *Errors, Miscues and Rotten Stories* section.)

One aspect of Forrester's vision about education entails student-centered learning and so the quicker we relinquish some portion of the notebook evaluation, the better off for all. Students will sharpen their critical judgment. Indeed, we have repeatedly found that students *crave* this; though unpracticed, students want to reflect on their own work. This holds true in writing as well as modeling.

Students compose this self-evaluation *as an entry*, working through the critical logic step by step, good practice that ultimately guides them as they find their own way.

- Record the number of entries since the last submission.
- Each entry ought to be approximately one page of drawings, notes, models, graphs, and/or writing. In a sentence, tell to what extent this describes your entries.
- Approximately how much average time did you spend composing each entry?
- Choose your best entry (choose your own criteria) in this recent period. Provide a VERY brief summary, and then tell what you did in this entry that makes it better than your others? You are free to choose more than one, but give a good case.
- Judge the quality and level of experimentation in your modeling and writing.To what extent do you extend yourself, either technically or conceptually? In which excerpt is this most apparent? Record this in about one to two sentences.
- Make a qualitative statement about how you have *changed as a modeler* since your last reflection. As you do this, use a specific model to help illustrate your learning.
- You may receive up to five [5] points per entry. Based on time, fullness of thought, and growth, determine your points. For example, if you had seven entries, you are eligible for up to 35 points. Thus, please express your score as a fraction, e.g., 32/35.

Students submit their notebooks after the self-evaluation. I then flip through them, focusing on items that catch my eye, read something here or there, add a comment perhaps, and then record the score they gave themselves. Before I return notebooks, I always read or present the great examples, opening the floor for some discussion.

In the years I have done this as a writing instructor, students are more persnickety about themselves than I. Certainly, and for valid reasons, I retain the right to override a score, but in 14 years I have done so only once. Besides, as the course unfolds, I talk with students about models and stories and other ideas enough so that I have a pretty good idea of what each is considering.

In the end, the notebook is for them, their collected wisdom and understanding, some wild thoughts, some speculations that may later prove fruitful. In other words, it is akin to a studio, a place where things unfold, few ideas are complete, and every idea carries forward the prospect of insight. Annotating a notebook, justifying scores with effusive commentaries, only trivializes what they have done. Go lightly: a nudge, a Forrester quotation, a question, a kudo—knowing that what you write there will stay in that notebook for a long time, but is ultimately less important than what comes of a student's own hand.

Errors and miscues and rotten stories

The most essential gift for a good writer is a built-in, shockproof shit detector. This is the writer's radar and all great writers have it.

—Ernest Hemingway

Notebooks share a noble lineage in numerous professions. One need only glance through facsimile notebooks of Michelangelo, William Blake, Chiam Potok, Henry D. Thoreau, or Mary Shelley to understand that these books are conveyors of raw thought. They are also a profound gift of great intellects laid bare on a page. How do great thinkers think? Their notebooks show us—they are filled with mental models.

What kinds of things they show is crucial. Universally, they show raw ideas ruthlessly edited by a honed, artistic sensibility: rough drawings, erasures, glossings affixed to poems, whole lines struck, rewritten, struck again, maybe even summarily pitched into the abyss. Objectively, therefore, one might say that notebooks depict errors; subjectively, however, notebooks depict diligence. The problem, of course, is that our schools scorn the former and generally ignore the latter, tossing aside the whole approach and nullifying this noble virtue. Indeed, do we not all chant the systems' mantra, "All models are wrong, some are useful"? Our entire approach is to seek truth, to approximate the real, starting—as *all* humans do—with a limited understanding, and then, incrementally, *diligently* moving toward what's true. It is, as I've mentioned, hard to evaluate. At an institutional level, notebooks are inefficient; at a personal level, however, notebooks are invaluable.

Frustrations may appear, breakthroughs now and again, but in most cases, the notebooks display a steady paced, forward move through new territory. Just as an explorer hacks away at obstacles as he strikes out on a trail, so, too, the artist leaps out to new vistas. There seems always to be a foot in the known, and another foot stretching into something new, one foot instructing the other: experience steadies, giving anchor to the reaching foot; risk pulls, giving impetus to the holding foot.

Every page of a notebook reveals the mental model of its creator. These are what we wish to expose, to lay bare, to test, to evaluate, and ultimately to improve—we want students (and ourselves) to have better mental models. The only way this will happen is to allow students to do this, to think. In a way, we need to *celebrate mistakes*, honor them for what they contribute to a modeler—the bracing fact of a start. So long as a student studies and thinks, the flawed model has a place in the notebook because the modeler will ultimately come to recognize the errors and incrementally work to reduce them. Error teaches. Insight and learning flow from such diligence.

This happens over time, perhaps a long time. The accumulated effect of this dialectic—the student proposing, the teacher suggesting—is that the modeler's systemic intuition sharpens; she can see. But the notebook cycling of student to teacher back to student and onward must have an appropriately brief turn time: no more than two weeks in a student's hands, and no more than two *days* in a teacher's. Give the student time to battle the idea, the model; and then let her know as soon as possible what you think about her ideas. Honesty, affirmation, expectation will go a long way toward extracting the gold in your student's mind.

If our task is to train a thinker, teachers ought to focus on the notebook, using it as a basis even for lesson planning. What it will show is a mind at various places of growth—skill sets at variant levels, concepts with omissions as well as insights, conclusions that are both faulty in one way and facile in others. In some cases, a young modeler will note the counterintuitive behavior of populations when connected to a resource (the fast rise in a population is only possible when sufficient resource is available, but it also spells the population's doom; once the resource declines, the population stares into empty, or near-empty, bowls). That same modeler, however, may also omit basic feedback loops as she draws or carelessly numerates an equation. Or, perhaps, after reading a round of notebooks, the teacher will note that most students did not adequately understand a multiplier, and how, for instance, it may mitigate a flow. Each of these instructional needs is crucial for a teacher to know. Consequently, a teacher ought to maintain a pedagogical or instructional journal of his own, noting the leaps and stumblings of his students. As the teacher works his syllabus against such weekly notes, he will undoubtedly ensure a closer connection between what he wants, and what the students need.

If we return for a moment to that notebook model of intellectual development, we should readily conclude that our mistakes—*errors* in our mental models—can guide us as ably as our answers—*accuracies* in our mental models. Therefore, acknowledge each student's attempt on a notebook page as *genuine*, *authentic*; doing so validates them as thinkers, as Socratic poets—as makers of meaning. And that is precisely what students are doing—constructing sense from the phantasm of life that shifts and shakes before their eyes each day.

Do we not honor "trial and error"? Why, then, do we so despise it in our schools, a relatively closed and safeguarded place wherein students ought to err; someone (in most cases, *many* someones) is ready to help and instruct. Out in the world, helpers are hard to find. A culture based on right answers construes such methods as weak, but it is exactly the way people learn, the way organizations learn, the way science unfolds, the way writers write, the way musicians compose, the way artisans create, and the way all thinkers creep closer to the truth.

I believe students really do want to know things—not so much the *what* and *when* of this world; schools have pummeled them with this minutiae for years. No—what

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Communication Using Systems Thinking and Dynamic Modeling in K-12 Education

June 30 - July 2, 2004
Skamania Lodge, in the Columbia River Gorge, Stevenson, WA

Keynote Speakers:
George Richardson and John Sterman

The Systems Thinking and Dynamic Modeling Conference will provide resources and opportunity for educators and interested citizens to explore what is current and possible in K-12 systems education.

The Conference is designed to involve experienced individuals as well as novices in K-12 systems education.

- Teachers
- Administrators
- Curriculum coordinators
- Citizen advocates
- Business partners for schools

Presenters include:

- Teachers and administrators actively involved in systems education across the country and internationally
- Internationally known speakers and professors in the field of systems thinking and system dynamics

Our presenters and attendees will address multiple interests:

- Use of systems tools to facilitate communication in both classrooms and organizations
- Use of systems tools to facilitate critical thinking
- Learner-centered learning and dynamic modeling as part of the curriculum
- Current action research initiatives
- Improving the quality of education within local schools
- Lifelong learning and creativity in students and teachers

Our goal is to help students/future employees be self-motivated and have the critical thinking skills necessary to look at dynamic systems in an increasingly complex technological society.

The conference program topics include:

- Tools for understanding and communicating in the classroom and in school administration
- Successive improvement—how have we done it? What are the markers of our failures and triumphs?
- Where has SD made a difference? How do we assess ourselves?
- Systems Education Pathways—from varied entry points, which paths have/have not worked? How do we create them?
- System Dynamics—a vehicle for collaboration and questioning
- Presentation of systems curricula developed by teachers
- Games that illustrate a systems perspective
- Time to exchange ideas with others about systems education for K-12

The conference will run from registrationWednesday morning, June 30, to Noon, Friday, July 2. For further information, call or e-mail Andi Miller at the Creative Learning Exchange.
978-287-0070
milleras@clexchange.org

The conference brochure will be mailed in December.

Skamania Lodge is a full service resort located on 175 wooded acres in the heart of the magnificent Columbia River Gorge National Scenic Area, only 45 minutes from Portland International Airport and 2-1/2 hours from the Oregon seacoast. The conference center and hotel provide flexible meeting space, comfortable guestrooms with extra amenities and spectacular views, award-winning Pacific Northwest cuisine, and a lounge open until late in the evening. Golf, tennis, walking trails, pool and fitness center are available on site.

Conference Registration Fee

The conference registration fee, per person, Wednesday AM – Friday Noon, is $435.00. (Late Fee: add $50.00 to this rates after May 15.) The registration fee includes the conference, five (5) meals—lunch and dinner on Wednesday, breakfast and lunch on Thursday, and breakfast on Friday—and a continuous break buffet. Registrants must make their own lodging arrangements.

There are three ways to register for the conference:

1. Register on-line at www.clexchange.org with credit card payment.
2. Fax your completed registration form with credit card information to 978-287-0080.
3. Mail the completed form, with payment, to us.

Registrants must make their own lodging arrangements. To reserve a room at Skamania, please call Skamania Lodge at 800-376-9116. The room rate is $139.00 per night. There are some rooms

***Conference** continued on next page*

Call for Presenters

Are you interested in presenting at the 2004 Systems Thinking and Dynamic Modeling conference to be held June 30 - July 2, 2004 at Skamania Lodge in the Columbia River Gorge in Stevenson, WA? The theme of next summer's conference will be "Communication Using Systems Thinking and Dynamic Modeling in K-12 Education," with an emphasis on utilizing systems tools to better facilitate communication in learning, in teaching and in administration. The conference will include the following topics:

- Tools for understanding and communicating in the classroom and in school administration.
- Successive improvement–how have we done it, what are the markers of our failures and triumphs?
- Case studies approach–where has SD made a difference both in education and in the world?
- Many people enter systems education through various doors. How do we create paths from those doors? What paths have worked or have not worked?
- System Dynamics as a vehicle for collaboration and questioning.
- Tools for understanding.
- The future of SD/learner-centered learning in K-12. How can we contribute toward it?

Please consider presenting a session at next summer's conference if you have something to say on any of the above themes or if you:

- Have taught students how to communicate utilizing systems tools.
- Have utilized systems tools to teach or help solve administrative challenges.
- Have an effective piece of curriculum to present.
- Have a story about your progress as a systems educator.
- Have an administrative application of systems tools and techniques.
- Have a progress report on a plan to get systems education implemented in your classroom, school or school district (or all three).
- Have examples of learning achieved by students through systems education.
- Have students who are willing to share insights into their learning through the use of systems.
- Have created a sequence of curriculum that seems to work for your grade level in teaching systems concepts.
- Have insights into assessing systems learning.
- Have tools for assessment.
- Have an overview of how systems education fits into a curriculum for a certain grade level and/or discipline.
- Have used systems techniques to create learner-centered learning.
- Have used systems techniques to create interdisciplinary cooperation and curriculum.
- Have an effective way of introducing systems to neophytes.
- Have a good training session for more advanced participants.

Sessions will be approximately one and a half hours in length. Appropriate long sessions (2 1/2 hours) will be considered for the workshop session, especially for training at any level or for games such as Fish Banks.

Process for submitting presentations for sessions:

- **Feb. 1, 2004** –Submit an abstract via e-mail that includes the context and history of the session topic and the experience level of expected participants.
- **Mar. 1, 2004** –All authors will be notified of the status of their submission via e-mail.
- **June 1, 2004** –A final outline/ presentation or paper is due via e-mail for incorporation into the conference CD.

Additional Conference Information continued from previous page

held for early arrivals Tuesday night, June 29. Deadline for reservations at Skamania is May 15, 2004. The hotel rooms may be sold out well before this date, so register as early as possible to guarantee a room at Skamania.

Other lodging options:
Best Western, 3 miles away. For the special conference rate ($79.00 + tax, mountain view; $89.00 + tax, river view, phone 800-595-7108 and mention the ST&DM conference.

Econo Lodge, 1 mile away. For the special conference rate ($53.00 + tax/ single; $63.00 + tax/double), phone 509-427-5628 and mention the ST&DM conference.

To be assured of a place, especially at Skamania, please register early. Hotels in the area also fill at this time of year, so make all reservations as soon as possible.

Transportation Information

Blue Star Shuttle. 800-247-2272. $40.00 per person, one-way, Portland International Airport to Skamania Lodge. Call one week ahead to schedule roundtrip transportation; give conference name to get this discounted price.

White Van Shuttle. 877-774-9750 or whitevanshuttle.com. $65.00 1st person, $5.00 each additional person, one-way, Portland International Airport to Skamania Lodge. Call ahead.

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they really seek is the *how* and the *why*[7]; their own curiosity compels them to seek it out. Yet, all around, the world churns and blurs; it is a world at varied distance and speed, its lines hazy, a world of shadows and murky layers, things happening at such a frenetic pace that one can only glimpse darkly, and so students have little intimate understanding of it. Thankfully, good modeling and lucid writing, akin to adjusting a lens, focus our time-bound, dynamic existence into discernible patterns—"a unity of mind and nature," as Gregory Bateson would say.

Notes

[1] Barker, Kathy. *At The Bench: a Laboratory Navigator*. Plainville, New York: Cold Spring Harbor Laboratory Press, 1998.

[2] STELLA is produced and distributed by High Performance Systems, Inc. of Lebanon, New Hampshire. Check their website (www.hps-inc.com) for "Story of the Month" and subscribe to *The Connector*, an on-line magazine about systems thinking in a variety of venues including education.

[3] Leslie Martin's *Mistakes and Misunderstandings: Table Functions* is available through the Creative Learning Exchange at clexchange.org and catalogued as "SD1998-02MistakesTableFunct." This is an excellent short paper on particularly thorny system problems for young modelers. It is a must read for anyone wishing to capture nonlinear change in a model.

[4] Booth-Sweeney, Linda and Dennis Meadows. *The Systems Thinking Playbook.* Pegasus Communications, Waltham, Massachusetts, 2001. A wonderful accompaniment to any systems classroom as it provides teachers and students a variety of gaming simulations that illustrate a number of systems concepts.

[5] *Lessons for a First Course in System Dynamics Modeling*, Fisher, Diana, published by Summer Creek Press, Tigard, OR. Diana and colleague, Scott Guthrie, both teachers at Wilson High School in Portland, Oregon, explain how they have used news articles.

[6] SimHealth was a NIH-funded K-12 outreach institute led by Dr. Edward Gallaher and directed by Dr. Louis Macovsky. The organization created a system dynamics-based physical lab based on pharmacokinetics that includes a class set of labs with several lessons for middle and high school. Contact gallaher@ohsu.edu.

[7] Sterman, John. *Business Dynamics*, Boston: Irwin McGraw-Hill, 2000. Many other lucid imperatives reside herein.

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This article is available in its entirety from the CLE web site, clexchange.org, catalogued under Implementation.

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If you would like to invest in our effort here at *The Creative Learning Exchange*, your contribution would be appreciated. You may donate any amount you wish; perhaps $50.00 is a reasonable amount for a year. All contributions are tax-deductible.

Enclosed is _____ to *The Creative Learning Exchange* to help invest in the future of K-12 systems education.

Name _____

Address_____

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e-mail _____

Thank you!

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