Teaching with Loops That Matter (LTM) in the classroom

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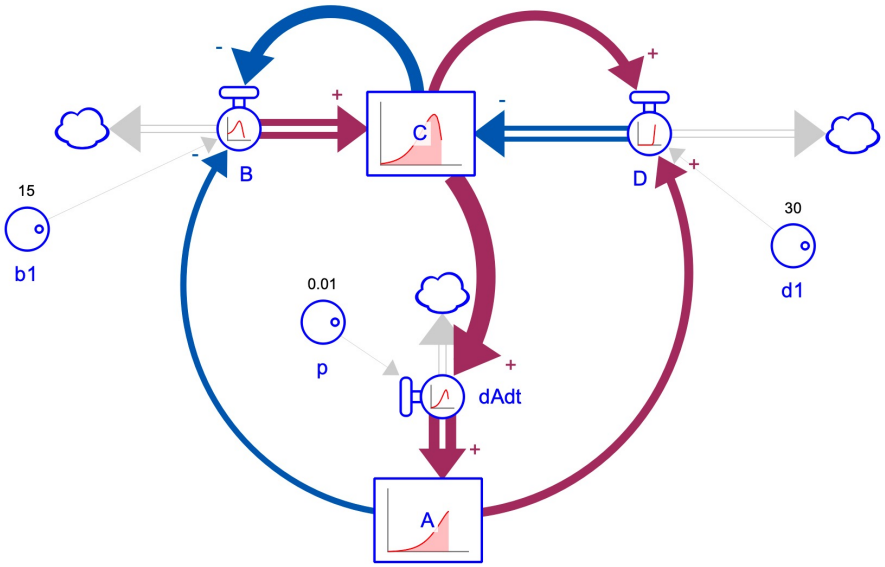
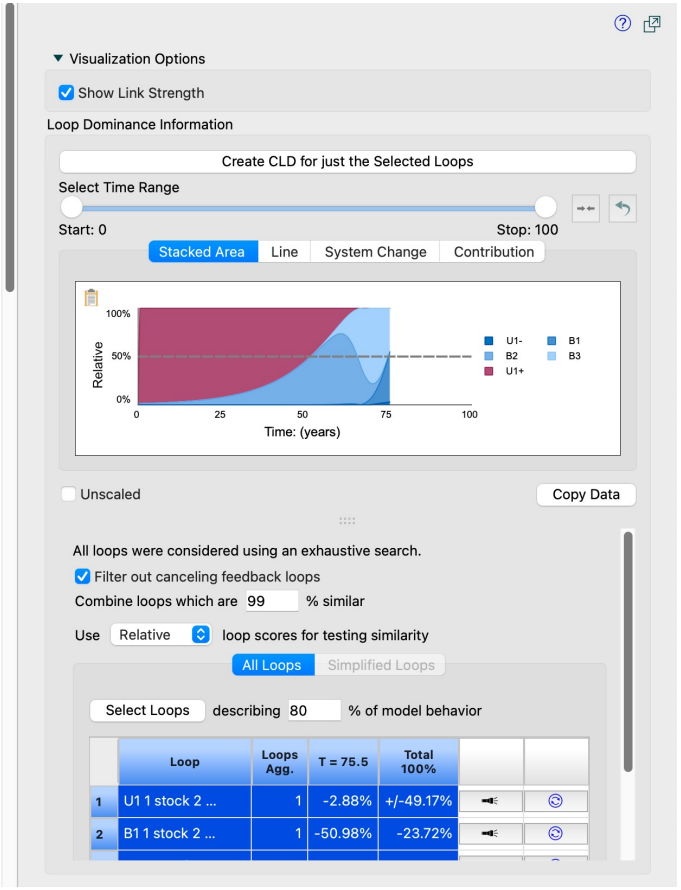
What is LTM?

- Method for algorithmically determining loop dominance
- Embedded directly within Stella since version 2.0 (2020)
- It yields Relative Loop Score, a metric which reports the contribution of a loop to the behavior of a model
  - Based on Loop Score which is based on Link Score
- Link Score calculates at each point in time the “responsibility” of the change in the independent variable for the change in the dependent variable.

Schoenberg, W., Davidsen, P., & Eberlein, R. (2020). Understanding model behavior using the Loops that Matter method. System Dynamics Review, 36(2), 158-190.

LTM measures and visualizes loop dominance…





One of the goals for LTM was….

To make it easier to teach the origins of model behavior and allow students to quickly understand why their models do what they do.

A problem was noticed @ UiB…

- The UiB master's program in System Dynamics has used Stella for over 10 years
- The professors and teaching assistants noticed something was wrong as new cohorts of students matriculated in 2021, 2022 and 2023….
- The newer students had a worse understanding of their models
- Students were shutting their brains off, and "letting LTM do the work"

It appears, at least anecdotally, that LTM without careful instruction is not encouraging learning.

A plan is put into action…

- We can’t stick our heads in the sand and pretend LTM doesn’t exist
  - The students know about it, and will use it – what student doesn’t like a “shortcut”
- Therefore, we must figure out how to teach students to integrate LTM into a process for developing model understanding!
- We decided to develop two lesson plans which are given to students ~3 months into their tenure with SD after they are already familiar with the basics of SD modeling.
- We had to teach the students how to properly use the tools at their disposal!

It was critical that students be able to…

1. Enumerate the feedback loops in their models
2. Tell a coherent story of what each feedback loop is doing
3. Understand the role of each feedback loop in creating model behavior
4. Understand how the interplay of the feedback loops causes shifts in loop dominance
5. Know how/when/if they can logically intervene in each feedback loop to change model behavior and describe why those intervention points are logical, and functional

Lesson #1: Feedback Loop Analysis and Narrative Building with Loops That Matter

- Learning objectives:
  1. Use Loops That Matter tools to construct a feedback narrative around the structure of any given model;
  2. Use Loops That Matter tools to analyze the feedback dynamics of any given model;
  3. Provide explanations for model behavior with respect to its feedback narrative and dynamics;
  4. Understand the concept of feedback loop dominance, interaction, and shifting dominance.

Lesson #1: Overview of activities

1. Introduction to feedback loop analysis (10 minutes)
   - Structure causes behavior/feedback perspective
   - Compare contrast with non LTM aided approaches
2. LTM tool demonstration with a small model (20 minutes)
   - Emphasize the speed benefits of LTM, but be clear that its not a replacement for critical analysis
   - Use LTM to enumerate feedback
   - Requires students to name each loop, and create a written process-oriented description of each loop
3. Group activity to analyze a larger model with LTM (45 minutes)
   - Small groups (2-4) assign them the analysis of models they are already familiar with
   - Require groups to name & describe each loop, and follow the process demonstrated in #2
4. Presentations (15 minutes)
   - Require each group to present their findings to the class – softly correct mistaken understanding for the entire class
5. Conclusion (15 minutes)
   - Reinforce the feedback narrative for behavior
   - The importance of loop dominance analysis for understanding why models behave the way they do
   - That LTM eases the burden of analysis, but still requires work – students **have to** understand the loops

* See supplementary materials for full lesson plan!

Lesson #1 Problems addressed

1. Enumerate the feedback loops in their models
2. Tell a coherent story of what each feedback loop is doing
3. Understand the role of each feedback loop in creating model behavior
4. Understand how the feedback loops interplay causing shifts in loop dominance

Lesson #1 leads students through the process of using LTM to create narratives about the origins of model behavior. It saves the students time vs. traditional manual approaches, and provides objective information (avoiding errors) on the polarity and relative importance of loops on model behavior

Lesson #2: Identifying Leverage Points for Systems Change with Loops That Matter

- Learning objectives:
  1. Use Loops That Matter tools to identify high-leverage loops in the system to intervene in;
  2. Use Loops That Matter tools to anticipate the system wide effects of intervening in the system;
  3. Understand the concept of leverage points;
  4. Provide high-leverage policy recommendations for systems change.

To understand leverage point identification with LTM, you need to understand “system change”

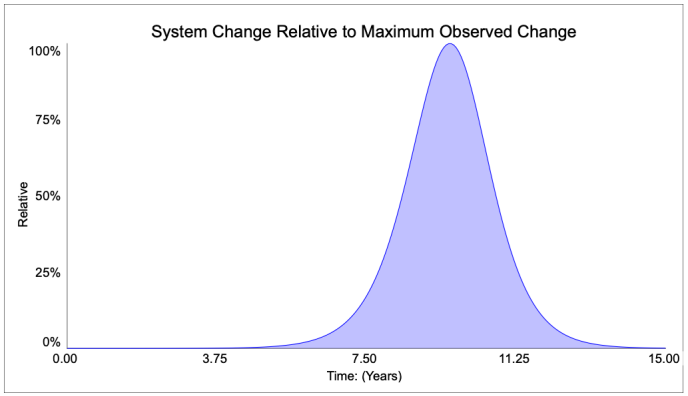
Schoenberg, W., Eberlein, R., & Davidsen, P. (2024). Measuring the change in behavior of a system with a single metric. System Dynamics Review.

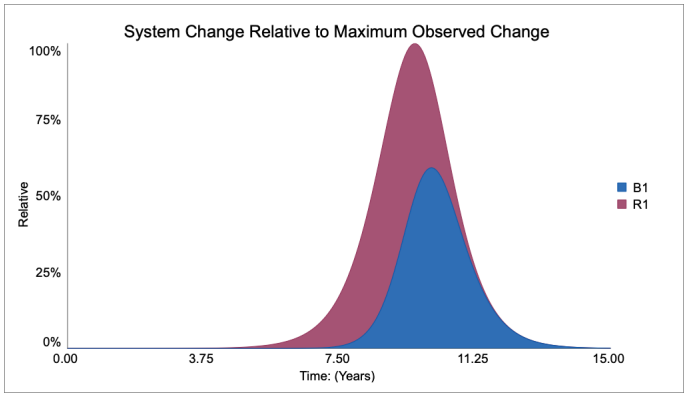
Quick summary of system change…

- LTM defines loop dominance as…
  - “We say that a loop (or set of loops) is dominant if the loop(s) describe at least 50% of the **observed change in behavior across all stocks in the model** over the selected time period.” (Schoenberg et. al, 2020)
- System change quantifies the above in bold into a single metric

System Change
In Bass Diffusion

The peak in system change is the inflection point in adopting





Lesson #2: Overview of activities

1. Introduction to policy analysis (10 minutes)
   - Recap univariate sensitivity analysis
   - Introduce high-leverage feedback loops, not just highly sensitive model parameters
2. Demonstrate identification of momentum policy options (20 minutes)
   - Recap the feedback narrative of behavior
   - Demonstrate how to use the system change plot
     - Avoid “event-based thinking” by tying system change back to the feedback narrative
   - Identify leverage points by studying dominant loops during period of large system change
   - Describe the policies which impact those leverage points and use the feedback narrative from Lesson #1 to explain why those leverage points work
3. Group activity to analyze a larger model with LTM (45 minutes)
   - Small groups (2-4) assign them the analysis of models they are already familiar with
   - Have them perform the analysis that was just demonstrated, and document their findings
4. Presentations (15 minutes)
   - Require each group to present their findings to the class – softly correct mistaken understanding for the entire class
5. Conclusion (15 minutes)
   - Understanding how & when to intervene in the system & understanding the system wide affects of interventions

* See supplementary materials for full lesson plan!

Lesson #2 Problems addressed

5. Know how/if they can logically intervene in each feedback loop to change model behavior and describe why those intervention points are logical, and functional

Lesson #2 leads students through the process of using LTM and system change to identify leverage points, and policies for impacting those leverage points. It teaches them to do this by building upon the feedback narrative of behavior from Lesson #1. LTM speeds up the process of figuring out where and when to look for intervention points.

We put these lesson plans into place in fall of 2023…

Lesson #1: We have seen… (the results we expected)

- The quality of model analyses and writeups submitted by students increased
  - There was more focus on narrative, and the feedback perspective
  - Overall, writeups were more grounded in structure than in 2022
- Students started with understanding the process captured by each loop, then went to the equations when curiosity about “why” arose, and a deeper understanding of the mechanics was needed.
  - The lessons helped to guide their search through the mechanics of the model (equation by equation relationships).
- Students were able to use the lessons and the software to tell coherent stories. The interpretability of the metrics in the tools were not a barrier to learning.
  - The students said, “How did you used to do this without LTM before?”
    - This opens questions about building the “intuition muscle”.

Lesson #1: Surprising results…

- Students found a middle ground between abstract disconnected “feedback” explanations, and mechanical equation by equation relationships
- Students ended up doing more structural validation then we expected
  - By pushing the students to study feedback from the process perspective it forced them to question how the model author chose to represent reality
  - They were checking for, and questioning “Right behavior for the right reasons”
- Keeping as much of the documentation generated by the students within Stella eased the process of understanding
  - Avoided context switching, and the feeling of “filling out forms”

Lesson #1: Practicalities

- Number of loops in the student analyzed model is directly linked to timing – 7 loops broke out of the 90-minute slot – 4-5 loops is better.
- Group size of 2-3 worked well, a pair is the best
- It didn't seem important for the students to be familiar with the model covered in the lessons before the lessons.
- Creating external materials to capture content discovered by the students seemed to get in the way
  - Rigorous worksheets where you fill in the full details of every step in the process were not an aid. Took too much time, and students were more interested in staying within the bounds of Stella.

Lesson #2: We have seen… (the results we expected)

- Thinking about how structure causes behavior, and how each feedback loop can be influenced led the students to better understanding of how to influence model behavior
  - This process provides a rigorous approach vs. the typical “random” search for high leverage parameters.
- Students weren’t just tweaking parameters, they were adding purposeful structures
- Being able to identify important periods, and the loops that are active during important periods (period of high system change) helps to focus attention on the “loops that matter now”.
  - By encouraging the students to think about how to influence processes in isolation before trying to do it in the model, students were much better equipped to discover impactful policy
  - When presented with a whole model, students tend to look for the “easiest solution” changing parameters, rather than the oftentimes better solution of adding structure
  - Forcing the consideration of adding structure, before looking at the system as a whole, “de-risked” the structure adding approach, making seem do-able.
- Students were able to explain why policies worked (or didn’t) using the feedback narrative skills from Lesson #1

Lesson #2: Surprising results

- From a TA of the course… It was a paradigm shift in the way we hunt for policies
  - This process provides a rigorous approach vs. the typical search for high leverage parameters.
  - This TA was had learned using more traditional approaches, and having a clear and methodical approach was comforting.
- Students discovered on their own that system change reacts to policy interventions, and were able to comprehend how the changes in structure they were making impacted the feedback story of the model, as well as the behavior generated by the model
  - It appeared that the students understood the rationale underlying the tools

Lesson #2: Practicalities

- It was critical that “exemplar” results from Lesson #1 were shared with all student groups that way all started from the same point.
- Keeping documentation within Stella worked well here too. Going outside of the tools broke their concentration

These lessons were among the students favorite and showed up in the course evaluations as positive experiences.

In conclusion…

LTM is an important tool for teaching System Dynamics, but it must be addressed in the classroom head on.

You cannot ignore LTM because your students won't, and without instruction LTM appears to not be helpful.

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