K12 Initiative Report

Prepared for System Dynamics Society Policy Counsel
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BACKGROUND AND INTRODUCTION

In May of 2015, "Promotion and Development of SD in K12" was added to the Policy Counsel's list of strategic initiatives. This additional strategic goal is in support of the long-term goal of introducing children in primary through secondary (grades K-12) schools worldwide to the principles of systems through the study of system dynamics.

The purpose of this report is to summarize and present a snapshot of system dynamics teaching in K12 in the US and to make recommendations for the policy counsel to consider.

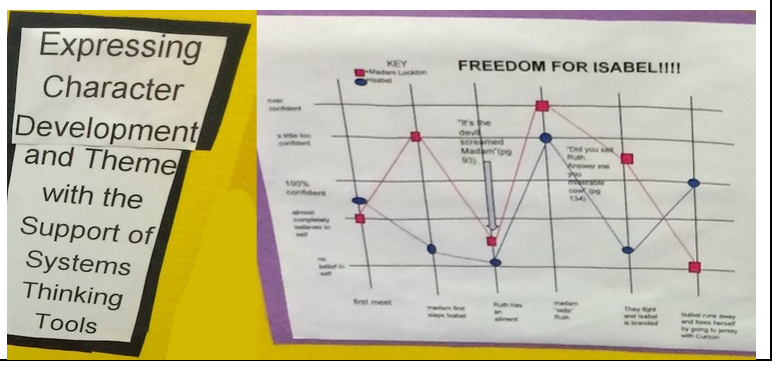
To understand the tools being used to teach system dynamics principles in US K12, three organizations were visited[i]. To gain an understanding of how people doing this work would describe a "promotion and development" effort, five K12 system dynamics leaders were interviewed[ii]. This report summarizes these research results.

SUMMARY OF FINDINGS

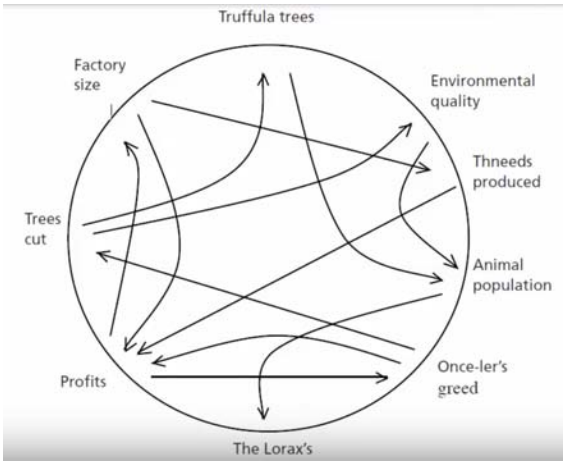
A significant body of work is being used in K12 schools in the US[iii] to successfully teach the principles of complex systems using system dynamics methods. In K12, system dynamics methodology is typically incorporated into an existing curriculum to recognize and analyze complex systems being studied (e.g. How does Romeo's love for Juliet change through time and; What causes his love to oscillate?). In K12, system dynamics is rarely taught as a stand-alone subject.

Many forward-thinking K12 teachers and administrators have dedicated their time to developing numerous K12 system dynamic tools. In the most successful efforts, recognized system dynamics experts have been involved, keeping the developed tools and techniques true to system dynamic principles.

While system dynamics focuses on creating and analyzing computer simulation models, the focus of K12 system dynamics is to build "system thinking" capacity among the constituents of K12 organizations. This is an important distinction that does not minimize the importance of the "system dynamics method" or "SD computer simulation models". While not all K12 students will become SD modelers, fewer will become great modelers if basic system concepts (e.g. accumulation causes delay; system structure causes behavior) are absent from the K12 education. System dynamics experts such as Donella Meadows and Barry Richmond have described building system-thinking capacity as "creating system citizens".



Many of the tools being used in K12 would be familiar to a person practicing system dynamics. Behavior-over-time-graphs (BOTG) are widely used to emphasize how values change through time. BOTGs are also used comparatively to add depth and detail to a description. BOTGs are also used



to help students identify important trends within a larger context.

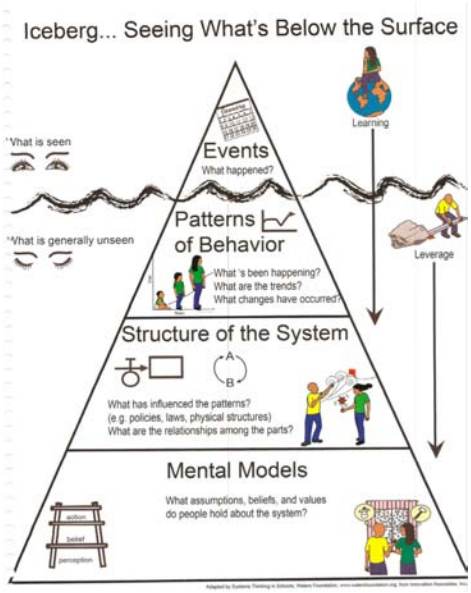
Causal loop diagrams (CLD) are used to emphasize interconnectedness and causality. Students are encouraged to explain their thinking about what is occurring by showing a hypothesized causal mechanism, especially if that mechanism is a closed loop. Although CLDs are often criticized for creating ambiguity, the emphasis in K12 is not on precise variable naming or polarity correctness. CLD learning is about being aware of causality and being able to construct and communicate a compelling argument. The "connections circle" exercise limits the number of variables being considered by placing chosen variables around a large circle. Causal connections are drawn across the circle with an emphasis on closing loops. Using connections circles students are taught to differentiate the stocks in the system by focusing on variables that grow (accumulate) and shrink.

Stock and flow maps (SFM) are used to build intuition about what is an accumulation, how accumulations change, and what effect they have on system behavior. Because SFMs can be "physical" some engaging kinesthetic activities have been developed. In one such activity, student teams are asked to fill a bottle with water as fast as possible without over-filling. The water must be added through a large funnel with a small outlet (creating a second stock). The "friendship game" involves inviting fellow students to join them at the front of the room (sometimes in a box outlined in tape on the floor). First, a single "seed" student makes the invites; then all students in the friendship stock make one invite each round. Graphs of students in the friendship stock show the difference between linear and compounded growth. (This exercise can be used to teach very young students about linear versus non-linear growth.)

Interactive simulation models are being used to build system-thinking capacity. "Living Lands – Forest and Town" is a multi-player simulation[iv] allowing students to explore a national forest and its nearby town. Decisions made by student teams impact the forest, the community, and the other teams. Materials used to understand the structure of the simulated system often accompany game simulations such as this.

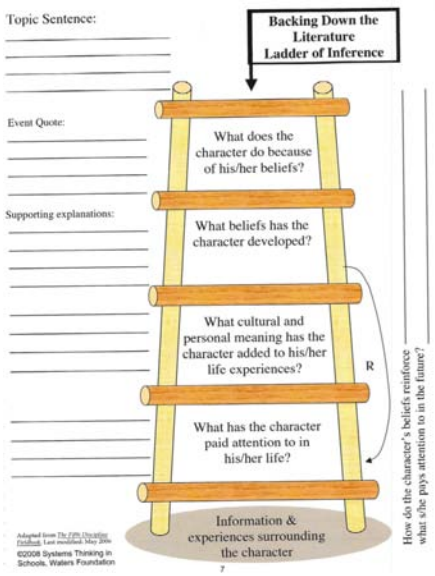
In addition, some older students (grades 5 through 12) are successfully experimenting with well-formed small SD models as well as formulating their own small models on a topic of interest. Successful grade 5-12 modeling programs exist in many subjects areas, including science, math, and the social sciences. Students in middle and high schools grades have successfully navigated the standard system dynamics method[v].

K12 teachers are using system behavior archetypes to describe themes present in popular K12 literature[vi]. Helping students to recognize generic behavior patterns (e.g. escalation) in stories that they study helps them to recognize behavior patterns and possible solutions in new stories or unfolding situations in their lives. K12 teachers have created new system archetypes, not generally seen in system dynamics literature, to describe other common K12 themes including: "story structure" (a theme of try, try again), and "revolution and repression" (a theme of dynastic cycles).



Other tools may be less familiar to system dynamics model builders. The "Habits of a System Thinker" is a poster of fourteen habits to practice when looking at the world through a system lens[vii]. Examples of the habits include: "seeks to understand the big picture"; "surfaces and tests assumptions"; and "pays attention to accumulations and their rates of change". The habits of a systems thinker also form the basis for a rubric used to measure a student's knowledge of systems concepts.

The "Iceberg" (The Waters Foundation) is a fill-in exercise, drawn as an iceberg pyramid with "what is seen" above the water, and "what is generally unseen" as the larger part of the iceberg below the water. Students can use the iceberg to investigate how system structure causes behavior. Students begin with observed events. Then they describe patterns of behavior over time that led to these events. Next they describe the structure of the system causing the important patterns of behavior. Finally, students are encouraged to think about their own mental models of the system (at the base of the pyramid) and how these beliefs are an integral part of the overall system. The iceberg process is similar to the system dynamic "standard method".



The "Ladder of Inference" (The Waters Foundation, based on The Fifth Discipline by Peter Senge) is a fill-in exercise, drawn as a five-rung ladder. Students generally back-down the ladder discovering how a person's experience and resulting beliefs act to filter the information being observed in an effort to reinforce one's closely held beliefs. With an appreciation for how observation is naturally filtered, the students are asked to re-describe the "facts" of a situation that are indisputable and available to everyone present.

These are some examples of the tools and techniques that have been developed to build system-thinking capacity in K12 communities. The sum total of these and other tools represent a significant body of work. K12 system dynamic leaders understand that not every person will become an SD modeler and that capacity building (understanding the characteristics of complex systems) is a difficult and worthy goal by itself. Temporarily relaxing some of the "SD rigor" allows the system-thinking education to be an age and level appropriate journey. A complete systems education includes different activities including: kinesthetic, descriptive, model using, and model building.

K12 SCHOOL COMPLEXITY

Teaching systems principles within the context of K12 grade levels brings several additional challenges. K12 schools are tasked with preparing the world's youth for the next stages of their education and ultimately a fulfilling and productive life. The importance of the K12 curriculum and its delivery is not lost on teachers or administrators. The current K12 climate in the US is weary of dealing with curriculum change amidst a focus on "teaching to the test". Teachers are often reluctant to embrace curriculum change (and the time required to adapt lesson plans) preferring to wait and see which changes "stick" while staying true to familiar teaching methods. While K12 schools are capable of change, effective curriculum change must pass a high threshold of documented efficacy and ease of adoption.

A body of research demonstrating the effectiveness of system dynamics as a subject or method for

teaching broad system principles is absent. A motivated and well-informed K12 teacher who successfully integrates the use of some system dynamic tools into her/his classroom will need to overcome significant challenges from other teachers or school administrators if her/his system dynamics teachings are ever to reach outside of that one classroom. Documented evidence of improved learning outcomes will be required to confidently spread the adoption of system dynamic teaching techniques. This is especially true in the face of many other proposed curriculum changes as well as limited budgets. A detailed definition of “improved learning outcomes” and the benefits to K12 schools could help direct such research.

Armed with compelling research, K12 administrators and teachers will require comprehensive support across several dimensions. K12 education encompasses a wide range of student ages (5 to 17 years of age), curriculum subjects, and diverse languages and cultures. Rapid adoption of system dynamics will require ready-to-use curriculum, teacher support and training, and the availability of required tools (e.g. computers or tablets and software) across all of the targeted age and subject dimensions.

PROPOSED K12 COMMUNITY SUPPORT

K12 educators are building systems thinking capacity. They are asking questions such as: Will future leaders be systems thinkers? Will they rely on rigorously constructed system dynamics models for guidance when facing wicked dynamic problems? While significant efforts are being directed towards building system dynamic capacity in K12, the rate of adoption is below what leaders in the field would like to realize. K12 leaders are actively seeking ways to scale-up their impact more rapidly.

What can the System Dynamics Society do to support these efforts? The following list is a summary of requested and actionable suggestions:

1) Encourage research on the efficacy of SD as a part of K12 education. (Does the research support our belief that SD in K12 will improve learning outcomes?) Present and describe these research results to encourage additional adoption of proven K12 SD practices.

2) Encourage research on what constitutes mastery of SD at different learning levels. (What do we want to teach? How do we know when the student has mastered each level?) Present and describe these research results to those developing K12 SD materials.

3) Develop metrics that can be used to measure the spread and level of success of SD in K12. Determine measurable goals over time.

4) Create a world-wide network of K12 contacts that are known to the SDS. Collect, track, and report metrics on K12 progress using this network. Create opportunities for support using this network.

5) Schedule time and "space” at the annual SD conference to recognize the importance of developing future generations of "system dynamics thinkers" and to celebrate recent accomplishments of the K12 educators using or teaching SD.

6) Organize a group of SD practitioners willing to donate time to interact directly with K12 educators. Goals could include: reviewing lessons and other materials for "good SD practice", creating an appropriate SD presence at conferences (outside of the annual system dynamics conference) that teachers are likely to attend, and spending time in K12 schools to develop research and support ongoing activities.

7) Fund a scholarship to support one or more K12 educators taking time out to develop the required SD based curriculum.

NEXT STEPS

Based on the information in this report, the policy counsel can discuss and determine a direction for the strategic directive: "Promotion and Development of SD in K12". My recommendation is that the policy counsel either:

- Determine that the this initiative is beyond the scope or mission of the System Dynamics Society and decide to drop or redefine the initiative; or
- Determine that the initiative should be structured to become an ongoing focus of the Society.

If the "Promotion and Development of SD in K12" is to become an ongoing strategic initiative, then I recommend that a small and temporary group be assembled to discuss and determine a way to structure the ongoing initiative for success. The following issues can be considered by the group:

1. This report is lacking an international perspective. A global perspective is critical.
2. The ongoing involvement of the K12 community is critical.
3. A statement of the K12 initiative purpose within the guidelines of the overall Society must be developed. What is the actionable and measurable purpose of this K12 initiative?
4. A description of initial priorities and anticipated resources could be developed.

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[i] Organizations visited:

- The Waters Foundation (attended the "System Thinking Level 2" class)
- George Warren Brown School of Social Work at Washington University in St. Louis (attended the "Community Based System Dynamics Institute" taught by the Social System Design Lab)
- System Dynamics Society Home Office - Rockefeller College of Public Affairs and Policy at the University of Albany SUNY

[ii] Interviews:

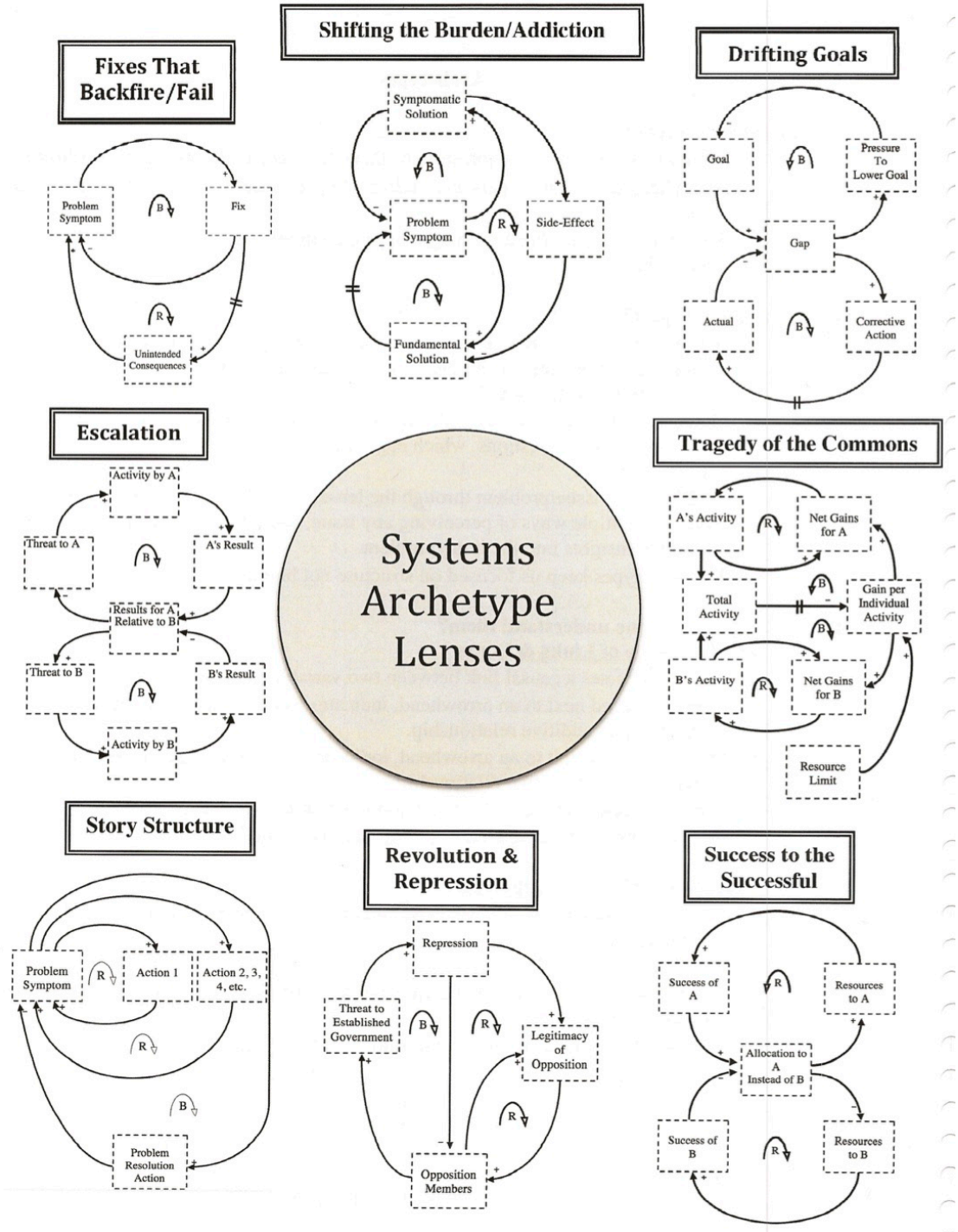
- Tracy Benson, President of the Waters Foundation for System Thinking in Schools (2015-07-10)
- Diana Fisher, author two educational books in System Dynamics: Lessons in Mathematics: A Dynamic Approach and Modeling Dynamic Systems: Lessons for a First Course, and a recipient of the System Dynamic Society's "Lifetime Achievement Award" (2015-07-11)
- Anne LaVigne, Director of Educational Technology for the Waters Foundation and Curriculum Resource Designer for the Creative Learning Exchange (2015-07-12)
- Lees Stuntz, Founder and Executive Director of The Creative Learning Exchange (2015-07-13)
- George Richardson, Emeritus Professor of Public Administration and Policy, and Informatics at Rockefeller College of Public Affairs and Policy University at SUNY Albany, a recipient of the System Dynamics Society's "Forrester Award," past President of the System Dynamics Society, and a long time supporter of primary school teachers creating SD curriculum (2105-09-09).

[iii] System dynamics is likely being used in primary schools in other countries of the world, however, the use of system dynamics outside of the US was not explored as a part of the research completed for this report.

[iv] "Living Lands – Forest and Town" was created by Jen Andersen, Anne LaVigne, Conrad Stuntz, and Lees Stuntz, with support from the Austin Family Foundation. The simulation can be found on the internet: http://www.clexchange.org/curriculum/simulations/livinglands.asp

[v] Examples of successful system dynamic student modeling programs include those at Wilson High School in Portland, Oregon; De LaSalle North Catholic High School in Portland, Oregon; The Carlisle School in Carlisle, MA; and DynamiQueST, an annual Creative Learning Exchange event held at Worcester Polytechnic Institute in Worcester, MA.

[vi] Recent "System Archetype Lenses" from The Waters Foundation:



Handout by Systems Thinking in Schools, Waters Foundation, www.watersfoundation.org, based on archetype described in *The Fifth Discipline,* Senge and by Innovation Associates, Inc.

[vii] Recent “Habits of a Systems Thinker” from The Waters Foundation: