

Next 25 Years in Education

The Next 25 Years in Pre-College Education: A Move Toward Global Understanding of Complex Systems

Appendix 1: More detail about survey respondent locations and level of use of ST/SD tools.

Key:

Occupation: T=Pre-College Teacher/Counselor, PD=Pre-College Professional Development Instructor or Coach, A=Pre-College School or District Administrator, R=University Researcher, UT=University Teacher, UA=University Administrator, C = Consultant, PA=Parent or Citizen Advocate (University respondents must have work directly related to using ST/SD in pre-college)

ST/SD Tools: Respondent survey scoring: 1 (never use), 2 (use occasionally in single lesson or unit), 3 (use regularly throughout year), 4 (infuse in class or work, selected as regular thinking tool)

For systems thinking (ST) the tools included BOTG, Ladder of Inference/Iceberg, Habits of Systems Thinker Cards, Feedback/Connection Circles, Causal Loop diagrams, Stock/Flow maps, and/or Use of pre-defined simulations.

t=maximum score of 2 on all ST tools, T = at least one 3 on at least one ST tool

For system dynamics modeling (SD) the only tool listed was that the person had students build or modify system dynamics models.

m=maximum score of 2 on this tool, M= at least a 3 on this tool

x= no ST or SD tool use

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North America	#	Occup	ST/SD	Europe	#	Occup	ST/SD
Arizona	10	T PD T PD T T A T PD T	Tm T T T T T Tm tm Tm	Finland	1	T	tM
California	3	A A T/PD/A	t T T	France	1	T	T
Colorado	1	UT	TM	Portugal	1	PD	t
Connecticut	1	T	T	The Netherlands	1	T	T
Florida	3	R PD T	TM TM t				
Idaho	1	PD	T				
Maryland	1	PA	Tm	Middle East			
Massachusetts	6	T A T T/PD T A	T t TM Tm TM Tm	Turkey	6	T T T/PD A T/PD T	T TM TM Tm TM Tm
Minnesota	1	T	TM				
Missouri	1	R	TM	South America			
Nevada	1	PD	t	Brazil	1	T	Tm
New York	1	T(ret'd)	Tm	Colombia	1	A	TM
North Carolina	2	R C	t x				
Oregon	4	T T T PD	x t Tm tM	Africa			
Pennsylvania	1	PD	TM	Senegal	1	T	T
Texas	1	UA	TM				
Vermont	1	T/PD	Tm	Asia			
Virginia	1	T	Tm	India	1	CurDevT	T
Washington (state)	4	T PA T T	TM tM T T	Thailand	1	T	tm
Wisconsin	2	T T	Tm Tm				
				Australia			
Coahuila, Mexico	1	C	Tm	New South Wales	1	PA	Tm

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Appendix II: The PreCollege St/SD Educator Survey Questions. (* Starred questions are required.)

Part I: Use of Systems Thinking/System Dynamics (ST/SD) Tools

- 1.* What roles have you had in pre-college (PK-12) education? (Check all that apply.)
 Teacher/Counselor Professional Developer/Instructional Coach School Administrator
 District Administrator Other _____ None of these (If response is none, please do not continue this survey.)

- 2.* What student age(s) do you (or if an administrator, your teachers) work with? (Check all that apply.)
 Ages 7 and under Ages 8-11 Ages 12-15 Ages 16-19

3. What subject(s) do/did you integrate ST/SD activities? (Check all that apply.)
 Arts (e.g., Art, Band, Drama, Music)
 Computer/Technology class
 Language Arts
 Mathematics
 Science
 Social Studies (e.g., Humanities, History, Government)
 Support (e.g., Study Skills)
 Other (please specify) _____

- 4.* Approximately how long have you been implementing/embedding ST/SD strategies within your work?
 Less than 1 year 1-2 years 3-5 years More than 5 years

- 5.* Indicate the level at which you and/or your students implement these strategies.

	Not at all	I use a few activities, and in individual lessons or in a short unit.	I apply more than a few times, when appropriate, spread over the year.	I embed in my work/class (e.g., students select a tool/strategy based on a particular need/focus).
Behavior-over-time Graphs (BOTGs)	___	___	___	___
Iceberg diagram and/or Ladder of Inference	___	___	___	___
Waters Foundation's "Habits of a Systems Thinker"	___	___	___	___
Connection Circles/Feedback	___	___	___	___
Causal Loop Diagrams	___	___	___	___
Stock/flow Maps	___	___	___	___
System Dynamics Simulations	___	___	___	___
Systems Dynamics Models (building or modifying)	___	___	___	___

6. If you teach your colleagues (other pre-college teachers or administrators) how to use ST/SD tools, please indicate which tools you teach them to use. (Check all that apply.)

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- Behavior-over-time Graphs (BOTGs)
- Iceberg diagram and/or Ladder of Inference
- Waters Foundation's "Habits of a Systems Thinker"
- Connection Circles/ Feedback
- Causal Loop Diagrams
- Stock/flow Maps
- System Dynamics Simulations
- System Dynamics Models (building or modifying)
- I do not teach my colleagues how to use these tools

7.* To what degree was using ST/SD strategies an effective way for students to learn class material?

1 2 3 4 5

Not at all effective Highly effective

8.* To what degree do you think your students learned more and/or thought more deeply by using ST/SD strategies than they would have otherwise?

1 2 3 4 5

A lot less A lot more

9. * In what ways have you gathered evidence of your students' learning while using ST/SD strategies? (Check all that apply.)

- Pre-test, post-test, quizzes
- Rubric assessment
- Written narrative
- Oral presentations
- Research paper(s)
- Portfolios (example: collection of multiple ST/SD work by student)
- Models created or modified by student(s)
- Teacher observation
- Parent observation
- Student self-assessment with rubric
- Other _____

10. What is one story you can share about how ST/SD impacts students?

11. Why do you embed or not use ST/SD in your work?

12. What best helped you to learn? (Check all that apply.)

- | | | |
|--|---|---|
| <input type="checkbox"/> Read about it | <input type="checkbox"/> Workshop(s) | <input type="checkbox"/> Webinar(s) |
| <input type="checkbox"/> Colleague | <input type="checkbox"/> Just doing it | <input type="checkbox"/> Professional Development |
| <input type="checkbox"/> Conference(s) | <input type="checkbox"/> Online course(s) | <input type="checkbox"/> Other _____ |

13. Other comments you wish to make regarding the use of ST/SD in pre-college education:

Appendix III: A detailed summary of the survey data.

The first question asked the respondent to classify himself or herself as a teacher, PD instructor/coach, school administrator, or other.

Those respondents falling into the other category included citizen advocates, parents, school board members, university persons (education professor, administrator), an advisor, curriculum developer, retired teacher, researchers, a consultant, and an extension agent.

Of the 72 final survey respondents there were 41 teacher/counselors, 19 (PD) instructors/coaches, 7 administrators, and 17 “other” respondents. There were overlapping counts by people who selected more than one job category. There were 8 respondents who were both teachers and professional development instructors it was decided to keep these respondents in the teacher category and remove them from the PD category. There was one administrator who indicated s/he was also a teacher and PD instructor. This person was kept in the administrator category and removed from the teacher and PD instructor category. There were 3 “other” category survey respondents who also indicated they were a teacher or PD instructor. Those three were removed from the “other” category and placed in the appropriate teacher or PD instructor category. There was one “other” respondent who indicated she was a school superintendent. She was placed in the administrators’ category and removed from the “other” category. The final category count for survey respondents was then: 40 teachers, 11 PD instructors, 8 administrators, and 13 others.

The second question asked the respondent to indicate what age group they worked with: ages 7 and under, ages 8 – 11, ages 12 – 15, and/or ages 16 – 19. (More than one choice was possible per respondent.)

Category	Ages 7 and under	Ages 8 – 11	Ages 13 – 15	Ages 16 - 19
Teachers	7 (17.5%)	13 (32.5%)	22 (55%)	18 (45%)
PD instructors	6 (54.5%)	6 (54.5%)	5 (45.5%)	8 (72.7%)
Administrators	6 (75%)	8 (100%)	6 (75%)	3 (37.5%)
Others	0 (0%)	6 (46.2%)	7 (53.8%)	9 (69.2%)
All 4 categories	19 (26.4%)	33 (45.8%)	40 (55.6%)	38 (52.8%)

The next question asked into which subject the respondent infused ST/SD activities: Arts (Art, Band, Drama, Music), Computer/Technology class, Language Arts, Mathematics, Science, Social Studies (Humanities, History, Government), Support (study skills), Other. (More than one choice was possible per respondent.)

Category	Arts	Computer	Language	Math	Science	Social	Support (study skills)	Other
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		Tech	Arts			Studies		
Teachers	3 (7.5%)	6 (15%)	11 (27.5%)	17 (42.5%)	23 (57.5%)	14 (35%)	9 (22.5%)	7 (17.5%)
PD instruct.	2 (18.2%)	1 (9.1%)	4 (36.4%)	3 (27.3%)	6 (54.5%)	4 (36.4%)	0 (0%)	4 (36.4%)
Admin.	2 (25%)	2 (25%)	3 (37.5%)	5 (62.5%)	3 (37.5%)	3 (37.5%)	1 (12.5%)	4 (50%)
Others	1 (7.7%)	2 (15.4%)	1 (7.7%)	4 (30.8%)	7 (53.8%)	7 (53.8%)	0 (0%)	7 (53.8%)
All 4 categories	8 (11.1%)	11 (15.3%)	19 (26.4%)	29 (40.3%)	39 (54.2%)	28 (38.9%)	10 (13.9%)	22 (30.6%)

Other includes: Sustainable development, environment, general understanding of systems thinking, professional development and coaching, gardening/botany, leadership, interdisciplinary project, STEM based classes, environmental studies, engineering, IB Theory of Knowledge, health, project based learning, PE & Health, Theme events, relationship management, organizational design,

Next we wanted to know how long the respondent had been implementing/ embedding ST/SD activities within their work? Less than one year (1), 1-2 years (2), 3-5 years (3), more than 5 years (4). (Only one choice was possible per respondent.)

Category	Average	Std. Deviation
Teachers	3.05	1.2
PD instructors	3.27	1.2
Administrators	2.5	1.1
Others	2.77	1.0
All 4 categories	2.97	1.1

The next question asked the level (1 = never, 2 = in an occasional lesson or unit, 3=in lessons or units throughout the school year, 4= infused as a regular thinking tool in work throughout the year) the respondent used the following tools: (Only one choice per tool was possible per respondent.)

ST: BOTG, Iceberg diagram/Ladder of Inference, Waters "Habits of a Systems Thinker", Connection circles/Feedback, Causal Loop Diagrams, Stock/Flow maps, System Dynamics pre-designed simulations.

SD: Having student build or modify system dynamics models.

Averages: 1 = none ... 4 = infused

Category	BOTG	Iceberg	Habits ST	CC/FB	CLDs	S/F Maps	SD Sims	Build SD Models
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Teachers: ave	2.73	2.20	2.35	2.40	2.45	2.15	1.83	1.90
Std. Deviation	0.9	1.0	1.1	0.9	0.9	0.9	1.0	1.0
PD instructors	2.55	1.91	2.00	2.27	2.27	2.27	2.00	2.09
	0.9	0.9	1.3	0.9	1.1	1.1	1.2	1.4
Administrators	2.13	2.25	2.75	1.8	2.00	1.63	1.13	1.38
	0.6	1.0	1.2	0.8	0.5	0.7	0.4	0.5
Others	2.77	1.92	2.31	2.62	2.85	2.38	2.23	2.31
	1.0	1.0	1.3	1.3	1.1	1.0	1.0	0.9
All 4 categories	2.64	2.11	2.33	2.36	2.44	2.15	1.85	1.94
	0.9	1.0	1.1	1.0	0.9	1.0	1.0	1.0

We wanted to know if the respondent taught any of the ST or SD tools mentioned above to coworkers, and if so, which ST/SD tools they used for this instruction. (More than one choice was possible per respondent.)

Category	BOTG	Iceberg	Habits ST	CC/FB	CLDs	S/F Maps	SD Sims	Build SD Models
Teachers	23 (57.5%)	17 (42.5%)	14 (35%)	21 (52.5%)	17 (42.5%)	15 (37.5%)	10 (25%)	11 (27.5%)
PD instructors	9 (81.8%)	5 (45.5%)	6 (54.5%)	7 (63.6%)	8 (72.7%)	8 (72.7%)	6 (54.5%)	5 (45.5%)
Administrators	4 (50%)	4 (50%)	4 (50%)	4 (50%)	3 (37.5%)	3 (37.5%)	0 (0%)	1 (12.5%)
Other	10 (76.9%)	6 (46.2%)	7 (53.8%)	8 (61.5%)	10 (76.9%)	5 (38.5%)	5 (38.5%)	5 (38.5%)
All 4 categories	46 (63.9%)	32 (44.4%)	31 (43.1%)	40 (55.6%)	38 (52.8%)	31 (43.1%)	21 (29.2%)	22 (30.6%)

Next a Likert scale (1=not very effective to 5=very effective) was listed for the respondent to indicate to what degree was using ST/SD an effective way for students to learn class material? (Only one choice was possible per respondent.)

Category	Average	Std. Deviation
Teachers	4.15	0.9
PD instructors	3.55	1.0
Administrators	3.75	0.7
Others	3.69	0.5
All 4 categories	3.93	0.8

Next a Likert scale (1=a lot less to 5=a lot more) was listed for the respondent to indicate to what degree students learned more and/or thought more deeply using ST/SD? (Only one choice was possible per respondent.)

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Category	Average	Std. Deviation
Teachers	4.18	0.9
PD instructors	4.27	0.6
Administrators	3.63	0.9
Others	3.85	0.8
All 4 categories	4.07	0.8

We wanted to know how teachers collected evidence of students' learning while using ST/SD: Pre-post tests and quizzes, Rubric assessment, written narrative, oral presentations, research paper(s), portfolios, models created or modified by students, teacher observation, parent observation, student self-assessment with rubric, other. (More than one choice was possible per respondent.)

Category	test	Rubric	Written narrative	Oral present	Research Papers	Portfolio	Student Models
Teachers	13 32.5%	16 40%	15 37.5%	22 55%	5 12.5%	15 37.5%	19 47.5%
PD instructors	4 36.4%	6 54.5%	6 54.5%	5 45.5%	4 36.45%	4 36.4%	5 45.5%
Administrators	1 12.5%	2 25%	2 25%	3 37.5%	1 12.5%	1 12.5%	1 12.5%
Other	4 30.8%	1 7.7%	2 15.4%	3 23.1%	1 7.7%	1 77%	6 46.2%
All 4 categories	22 30.6%	25 34.7%	25 34.7%	33 45.8%	11 15.3%	21 29.2%	31 43.1%

Category	Teacher Observe	Parent Observe	Student Self Assess	Other
Teachers	23 57.5%	4 10%	9 22.5%	0 0%
PD instructors	9 81.8%	2 18.25%	1 9.1%	2 18.2%
Administrators	7 87.5%	0 0%	0 0%	1 12.5%
Other	9 69.2%	3 23.1%	2 15.4%	4 30.8%
All 4 categories	48 66.7%	9 12.5%	12 16.7%	7 9.7%

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Other includes: conversations, post in-depth interviews with students, homework assignments, time on task and engagement research, see if bug population crashes or explodes, as part of text-based materials used for student research and presentations,

We asked what best helped them learn ST/SD: reading about it, a colleague, conference(s), workshop(s), just doing it, online course(s), webinar(s), Professional development, other. (More than one choice was possible per respondent.)

Category	Read	Colleague	Confer.	Work shop	Just do it	Online course	Webinar	Prof Devel	Other
Teachers	20 50%	17 42.5%	23 57.5%	28 70%	26 65%	7 17.5%	5 12.5%	13 32.5%	7 17.5%
PD instructors	7 63.6%	4 36.4%	4 36.4%	7 63.6%	9 81.8%	4 36.4%	2 18.2%	7 63.6%	2 18.2%
Administrators	3 37.5%	2 25%	5 62.5%	5 62.5%	3 37.5%	1 12.5%	1 12.5%	4 50%	0 0%
Other	7 53.8%	6 46.2%	7 53.8%	7 53.8%	11 84.6%	5 38.5%	2 15.4%	2 15.4%	5 38.5%
All 4 categories	37 51.4%	29 40.3%	39 54.2%	47 65.3%	49 68.1%	17 23.6%	10 13.9%	26 36.1%	14 19.4%

Other includes: visuals, Systems Thinking: A Primer, watching DVD for Systems Thinking Playbook, getting a Masters degree in Whole-Systems design, graduate coursework, Waters Foundation ST Collaboratives and teaching others, practice, Emre Göktepe talking about ST/SD, MIT Guided Study Program & Road Maps, courses at University of Bergen, Course at WPI, action research applying ST to critical messy problems in communities and schools, perseverance, support from professional groups and foundations especially Waters Foundation and Creative Learning Exchange, worked with Gregory Bateson and was taught by Barry Clemson and Stafford Beer, mentor, adults from all over wanting to observe my class (when adults come kids think what they are learning is important),

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Appendix IV: All comments to the question "What is one story you can share about how ST/SD impacts students?"

Teachers

- One of my students was assigned a speech to give about leadership at our school. She used Habits language, the ladder, and talked about the changes over time during a 2 minute speech. She was chosen to speak to our school board:)
- I started using iceberg diagrams to aid in setting goals for the year. Often student goals are product oriented. Iceberg diagrams help them uncover the higher leverage strategies that will help them accomplish their goals.
- One student did manpower models for aerospace company and was employed as an undergrad, telecommuting from college.
- A group of students studying the opioid addiction crisis in the US used feedback diagrams to look for leverage points to help the situation.
- Years ago I taught 8th Science...We used the PK lab/model and fishbanks every year, and they were highlights for the students. PK lab gave them real-time model interaction with a great tie to the real world (therapeutic zone). Fishbanks I used in ecology classes for years, kids absolutely loved it...I saw the convergence of disparate intelligences/interests...my capitalists immediately shined and pursued profit to the exhaustion of the resource base...my less "self-interested" or more "others-interested" students paused and spoke to me of the potential resource decline and the need for intervention. I've been teaching 6th grade for a long time now, fishbanks doesn't seem to be around now, and modeling itself is a stretch for this age.
- Students are better able to deal with complex environmental topics by first spending time with feedback games and simple models.
- In 2015-16 school year, I sponsored a ST/SD Club in our high school. A Boeing engineer volunteered to deliver lectures on ST/SD on weekly basis for a couple of months. The Club members learned causal loop diagram, etc. We did have pre-test, but we did not have post test.
- I was very surprised to see the same thing in the input and output of a student stock flow maps. In some stocks both entry and exit had the same effect.
- Using the graphics to process units enables student centered learning and helps ESL students to participate and process concepts in their own time. It has been very helpful this year as we went to Block scheduling. It allows the students to explore all the contributing factors of our health topics.
- I had a student who had little exposure to the Habits in a language arts class, and he found a connection in a history class that both teachers had overlooked. We were both amazed and impressed!
- Helping students make connections in World history lecture by using diagrams and visuals to supplement teacher presentation.
- I teach IB History, Africa Higher Level, and regular use of the ST Iceberg model helps my students retain micro- and macro-level details about numerous African countries' transitions to independence. Through demonstration, then scaffolding student use of the the model, they are able to independently apply the model to different countries we study. Using the Iceberg model definitely helps deepen their understanding of the often 50+ year-long independence process, it also enables them to compare and contrast different countries path to independence, leading, of course to even more knowledge and understanding that they are able to effectively convey both verbally in presentations, as well as in complex analytical writing assessments.
- Using connection circles for understanding how different factors interconnect to exacerbate long-term poverty helped my 10th graders understand the implications of real policies and laws.
- Students begin to think systematically and will at times initiate the use of System's tools to help solve or visualize a problem or concept. Tools are easily understood and utilized by students.
- The fear soldiers had in WW 2. IT doesn't matter if it were Germans , Japanese or French, British, Canadians or Americans.
- Students come alive when they are treated as intelligent, creative beings that are capable of seeing the world as connected. Boo to subject periods and Hooray to stretches of time learning to think systemically.
- Can I use the Insight Maker software to make a connection circle to show these relationships? she asked while taking a test with no prompting! Once students see the archetypes and build them for a situation they know, they can identify them in new places and situations like the substitution of BPS for BPA.

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- I have just started my project to introduce ST/SD to schools in France. I must say it does not appeal to teachers at first approach. So I have not trained teachers on the tools but rather suggested I can demonstrate the approach to them on an interdisciplinary project that can be taken up in the class together. / So I'm currently working with a middle school on an interdisciplinary study of wind energy. I used causal loops and feedbacks to orient thinking towards the far-reaching, unexpected, invisible consequences as well as time delays. I then brought the conversation to daily life experiences and suggested eating at Macdonald's. Several students could immediately see the invisible and long term consequences.
- Two of the preschool teachers I supervise had these stories. 1. "I asked students to sit on chairs. One of the students sat on two chairs. Another one said, "Don't do like that. You're depleting the stock," 2. "I once asked an open ended question. One of the students said, "It's a system collapse teacher, one minute please."
- I had students take an mbti survey to get data about how they solve problems and work in a team. We then used the data to create a cause and effect map about their system. Students found consequences and tried to create leverage items to avoid or decrease the impacts of the consequences. / / For example, one student found that once she settles on an idea she becomes rigid and refuses to change it, she created a leverage item to seek feedback after settling on an idea to avoid becoming rigid.
- My students really like using the Story Structure Archetype to help them map out a story. Many students were confused about the traditional problem/solution template of a story's structure. The Story Structure Archetype helps them to understand that sometimes characters try different solutions before they find one that helps them solve their problem.
- Feedback / Causal Loop analysis of environmental science helps students focus on the complexity of interactions. They provide a common framework that engenders quality discussion.
- Students were able to make connections about their own actions and environmental systems
- / My students learn the abstract concepts that are difficult to learn, thanks to SD, they learned it more practically and learned more easily...
- It is a never-ending story, not one. Many students, upon getting involved in their modelling, do not want to move to another class or to go home!
- I used to use the blood alcohol content model during a unit on drug prevention education. Students really learned how factors such as gender and body size affect alcohol intoxication. I have not used SD in my teaching for several years though since the health curriculum has changed. I could tell that my students understood how alcohol affects people at a much greater depth by observing the questions they asked
- My students are able to apply the models to differing scenarios when not prompted by me. This shows me they are self-initiating using the tools.
- None / I have very little experience with these but, but would like to know more

PD Instructors

- The students were asked to describe the equilibrium reaction $N_2(g) + O_2(g) \rightleftharpoons 2 NO(g)$ in terms of a ready made graph: Rate of Reaction over Time, and what is the change in the graph when the catalyst is added. / Afterwards the students were able to build a dynamic model of the equilibrium reaction and see the result matching the initial graph.
- K-12 district process started with all district administrators and teachers leaders for past 5 years being trained first. Now students, teachers, administrators using common language, tools, and on-going digital resources across buildings and grades. Real progress seen when organizational clarity and all stakeholders (including parents and community leaders) are engaged in using tools. Only way to make ST sustainable. If a building principal uses ST - staff, parents, and students see relevance. When School Board and Superintendent use ST tools to explain decisions and solve problems - the teachers, students, and curriculum are impacted on a deeper level than 'just another new thing' or teachers sent to professional development that is forgotten and dropped in a few years.
- 5th grade students working on a project around the driving question, "What will be the outcome of your current lifestyle in 10 years?" began their project by tracking the nutrition value of the food they ate each day, the amount of sleep each night, and the amount of daily exercise on BOTGs. After a week or so of tracking, they were asked to pull out all three BOTG's and look for connections across their graphs. For example, if they noticed a change on one day, they were encouraged to see if something had changed on that same day on another BOTG. Many students noticed that a lack of sleep correlated with decreased exercise the following

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day. They also realized, more importantly, that many students in the class did not regularly eat breakfast or tended to grab a Pop-tart or a piece of toast. This particular class was struggling considerably in math, their first instructional period of the day. They concluded that perhaps the lack of a decent breakfast was affecting their ability to stay focused and their performance in math. Needless to say, lights went on for many.

- In a 9th grade general science class called Principles of Science, students studied the Rapa Nui human population change via online SD simulation, as well as creating their own BOTGs, CLD, and stock and flow diagrams on "big paper" at their tables. Using the standard stock and flow structure they created for the Rapa Nui example they were able to answer questions about issues of sustainability related to their own city in modern times and Earth as a whole. They created parallel models to note the similarities between a problem the considered long ago and far away and present-day issues of sustainability. Transferring these concepts would be much more challenging were it not for the SD/ST tools we use in class.
- Students in an AP English class created BOTG to track their own progress on AP-style prompts and assessments, then integrated understanding about growth mindsets to make adjustments to their own learning strategies and approaches.
- Students create impressive original models, can write technical papers explaining their models, and can do presentations to the class about how their models work.
- We have a very small school and the 8th grade in particular has only 7 students. We used the habits, causal loops, and the Play Book activities to build relationships among those students. It has been successful enough that we will be expanding it to the rest of the MS students.
- ST/SD dramatically improves Media Studies student capacity to model human behavior as affected by social media.

Administrators

- A middle school student I mentored had a troubled childhood and made plenty of poor decisions. He worked in my office two periods a day and was surrounded by the Habits Posters hung on the walls. I don't know how many times I referred to unintended consequences with him. Year passes and he spent a brief time in jail. We connected and I asked him if he remembered the Habits. He said if he had paid better attention, he probably would not have gone to jail! Some lessons are harder to learn but when they sink in, they are set in stone!
- We are in the beginning stages of learning and using the ST strategies and tools in the classroom. The bulk of our work over the past two years has been training and using the tools/strategies at the management and leadership level. A core group of pioneer teachers are using the strategies as they learn them.

Others

- After asking for botg AFTER study doing simulating they get that they get it. Or they get that they are going to get it.
- My best story is of Dexter, a 6th grade student. Through guided development of a simulation model of the electric motor each student was building in his class, he learned about air resistance and frictional resistance. I noticed a statement in a book chapter on electric motors that claimed that designers of electric motors intentionally build resistance in their motors because if they didn't, the motor would go faster and faster until something broke. I asked Dexter if he had intentionally designed resistance into his motor. He said he hadn't, yet he realized his motor didn't go faster and faster until something broke. Rather, the fan it was driving seemed to reach a fixed number of revolutions per minute. So, he was curious. Was the statement in the book wrong? Or was there unknown resistance in the motor? Armed with a stopwatch to time how long it took his fan to reach its terminal RPMs, and STELLA, Over 2 to 3 days after class, Dexter developed (with my coaching) a simulation model that mimicked the growth in RPMs. Along the way he discovered air resistance to the fan, and frictional resistance in the fan's shaft bearing. He demonstrated his model to the class using STELLA and a PowerPoint presentation he developed. The next summer, he coached teachers in the use of STELLA in a class that Jeff Potash and John Heinbokel facilitated. The teachers were really surprised, I think Dexter was a low-B average student from a divorced, poor, mixed race family and was saddled with several three-letter-acronym conditions, including ADD. I wonder where Dexter is today...

Next 25 Years in Education

- I have worked with ST/SD with teachers and students (mostly middle and high school). They seem to both have the same learning curve for using the tools and eventually coming around to be excited about their use. My favorite experience is during a teacher workshop where teachers from across many disciplines realized how they could use several systems thinking tools in their lessons, that they weren't solely science based. And students really enjoy that there is not always one right answer with systems diagrams, that they are now challenged with defending their answer instead of just trying to "get it right."
- I used ST/SD in a series of workshops to engage adolescent students around obesity prevention. This is a quote from one of the students during a post interview that sums up the impact he perceived, "once I got it, it was a whole lot that was going on through my head and I wanted to make my own chart [referencing the causal loop diagrams], it overwhelmed me because and I finally knew how to put things in the correct spots."
- none at this time
- Students have shared that they now apply system dynamics to the way they think about choosing colleges and completing homework.
- I would say that most of the System Thinking tools are not hard to be understood by most of the students. / / Nevertheless, I need to combine System Thinking with competences as the latter has been broadly used in Mexico as the main stream for education. / /
- A 12th grade girl student from India identified 16 environmental factors that affect growth of a plant sapling in her backyard garden.

Next 25 Years in Education

Appendix V: All comments to the question “Why do you embed or not use ST/SD in your work?”

Teachers

- I embed ST tools into my curriculum because it is a visual way to represent what my students are thinking. I love watching light bulbs go on as students analyze text and see all of the connections!
- Effective way to get students to think about a problem in a deeper way.
- I teach a course called "Wicked Social Problems". No other approach works. I teach a course called "Sustainable Systems". No other approach works.
- Many reasons - dealing with complexity, quantifying variables (hard and soft), better communication, deeper thinking and learning, compassionate understanding, ... overall, systems thinking and system dynamics adds value to most curricula.
- I used it a lot while teaching 8th grade science.
- Embedded as a way for students to construct an understanding of how systems impact their lives.
- I don't know enough or am not confident enough to embed ST/SD into the curriculum.
- Philosophical thought / * Cause result relation (causation) / * Awareness
- There is a lot of work to be done due to the curriculum.
- I try to embed the various problem solving structures into the various units so that they can use these structures when faced with a different topic or problem. However, my limited time with students (10 weeks every other day) can make it difficult to introduce the new ways to approach problem solving, because just as much time is required to explain the graphic organizer format. I'm attempting to have these be presented in a Freshman Academy course. Stay tuned.
- I am one of the few in my school that use ST, and find that it was easier for me when students had some prior knowledge. I feel I don't have time to always introduce the tools as we are so focused on test scores and it is a push to get through the curriculum.
- I try to embed it into all my work to model the use of it so others may adopt its use.
- ST is the best professional development I have ever had. I believe it helps prepare students for life beyond school, and can be applied in every area of life. It is fun to use in class, the students are engaged, and it definitely works to get students to go beyond the superficial, and succeed.
- Systems thinking is a must for having a deep understanding of the complexity of all issues and organizations. It gives students a way to understand leverage points for change.
- Referring to the Habits of a System's Thinker provides students with ways to categorize concepts being studied and learned. They begin to make connections. This helps them understand at a deeper level.
- How can we not embed it?! It's indeed life itself...as educators we must teach about life.
- embed as often as I can while meeting NGSS
- Can't say much for the time being. As I mentioned earlier, I am on my first project and plan to try introducing these tools over the current year in various circumstances and would be better off for responding on this later in the year.
- Principal suggestion
- It's important for kids to learn
- I impeded Systems Thinking in my teaching because I believe it is a very visual and concrete representation of student thinking.
- My own understanding of the world is deeply influenced by the ST/SD lens so it is natural for me to embed it in my teaching
- It helps students to see how systems work in real life
- To promote systems view and thorough grounding in the subject matter.
- I don't have many opportunities to do so now a days
- It provides a set of tools for students to use to more deeply analyze their worlds.
- SD was limited by other classroom commitments.

PD Instructors

Next 25 Years in Education

- We need to teach problem solving, higher order thinking skills, and new technologies to prepare our children and young people for the challenges they face everyday and in their future.
- As a classroom teacher, I saw how much more deeply my students understood concepts when we used systems tools and habits. They quickly grasped concepts related to balance in ecosystems, including important ideas about carrying capacity of an ecosystem, keystone species, and other concepts not normally included in a second and third grade science curriculum. Systems tools help students consider the effects of their actions and help them look for solutions to social/emotional problems. They can track their progress in any area using BOTGs, allowing them to see their own growth and feel affirmed. I see so many advantages with respect to curriculum and the social nature of school and community.
- I love BOTGs especially, because they allow easy access for students at multiple levels of understanding, and really create a platform for kids to explain their reasoning, debate alternate depictions/predictions of behavior within systems, etc. // They are very low-tech, and easy to set up and use - the leverage is very high.
- I have found that SD empowers students to understand the connection between accumulations and rates of change better than other methods I have used. This is a way to have algebra students gain a conceptual understanding of introductory calculus concepts.
- I hope to continue embedding ST/SD at the MS level and then expanding the tools both up and down to include K-12 students. However, we are starting slowly. Even though there are few teachers and students, there is resistance to trying something new. These tools/habits are also being shared with teachers at PD. It will take time ... // I choose to take on the challenge of embedding ST/SD because I have seen it benefit previous districts and it has helped me do some problem solving of my own, both work-related and personal.
- It provides critical thinking skills.

Administrators

- I am not yet comfortable with the ST/SD tools and thinking about how to implement them in my work.
- Difficult to implement info lessons
- I use it to help people see the connections and impact of their decision on others and in their work.
- As the superintendent of the district, we are committed to identifying issues of racism in inequity in mathematics that keep students from being academically successful. We are using the PLC model as our road map, ST/SD strategies and tools to guide our discussions and decision making, all with the goal of eliminating the systems we created that cause and foster inequity, and replacing them with systems that promote and sustain equity and closing the opportunity gap. We have worked extensively with Peter Senge to train our leadership/administrative team, and we are part of two Stanford research projects that are funded by the Stuart Foundation. My goal as the superintendent is to build a firm foundation of good decision making through the ST strategies and tools and to continue our equity work in the district - long after I am gone.

Others

- Hmmmm...
- I do in my paid work at Boeing. Working with teachers and students is a volunteer activity.
- Right now it is my dissertation topic, so I can't get away from it. While unfamiliar with it at first, I now see the value and hope to see it more in K-16+ education. My personal interest is environmental literacy and I truly believe that if students understood natural systems better, they would consider the impacts of their actions more.
- It provides helpful tools to think differently about complex problems.
- program goal
- Not accepted the school yet
- We are interested in gauging how people change through SD and whether learning it during adolescence can change individual behaviors and choices.
- As I said before System Thinking concepts are logical and relatively easy to understand. Possibly with the exception of the habits of How Mental Models affect current reality and the future and the Surfaces and Test Assumptions. I think they overlap each other in some extent.
- It helps students to think more deeply about a subject, enhances critical thinking, deepens understanding and encourages empathy.

Next 25 Years in Education

Appendix VI: All comments to the prompt "Other Comments."

Teachers

- Changed my life, curriculum, teaching, and outlook on Politics:)
- I am hopeful the use will spread. ST/SD adds value so clearly that other disciplines should include the tools and principles regularly in training and practice.
- To get more K-12 educators involved
- I think that it is very useful for the visualization of abstract information in terms of concretization and visual reading. It also improves the skills of students to predict and deduce. Makes the students understand the big picture. It makes it easier for students to sort events and establish cause - effect relationships.
- I would love to have more online learning opportunities or workshops geared specifically to my subject matter and school level.
- I miss working with the Waters Foundation staff!!
- I was fortunate to get my start in ST in the Catalina Foothills School District with Anne LaVigne and Joan Yates. I wish they were still colleagues to whom I can turn to for collaboration and inspiration. I now teach at an international school in West Africa and am the only teacher on campus with this background, it's a lonely existence. I need to go to a ST conference to meet more ST folks. :)
- Do it with all your colleagues together, otherwise it will fail using it on the long term. I saw it in my school in Maastricht, the Netherlands.
- If you ain't using it - you ought to be!
- Extremely important for natural resource professionals, interpretive naturalist, EE folks and teachers for the Oregon Environmental Literacy Act and Outdoor School.
- What I find the most difficult is to communicate on what ST is. Whatever way you present the notion, nobody seems to have the patience to even hear it out !! The teachers I am currently working with today claim that what I have done so far in their classes is extremely interesting but my presentation wasn't that great and in fact almost dissuaded them. On that occasion, I had 15 mins to present what ST was.
- I wish there was a class where it was just teaching systems thinking, instead of how you would apply it to subject matter. I would love a webbed connected to that. That is what I'm trying to do and I can't find many resources on how you would teach systems thinking on its own. I'm cobbling things together using your site and something from the institute of play.
- Difficult to implement when there is not a support system of others also using it or willing to learn.
- Wish it was more widely accepted/implemented

PD Instructors

- After 40 years in public education, teaching ST from kindergarten to graduate schools, using it as a school Superintendent, and supporting multi-year projects with schools across the US, Canada, and overseas for the past two decades - if district leadership does not understand, embrace, and use ST - it is not sustainable over time. It's everywhere or it's no where. / / I think the ST community and groups that support 'the work' need to review where and how they are putting their energy and resources.. Over the past years attendance at major ST conferences and trainings continue to decline. I don't meet many school leaders involved. Building level leaders, with support of central office, are the most critical people to move ST forward with teachers and especially impact student learning. / / Are we applying a systems approach to our own work.
- It's very important. Everyday when I read the newspaper or watch the news on TV, I see examples of people who don't use systems thinking and wonder how much better we'd be able to solve difficult problems if more people did. Our kids will inherit many critical problems. Systems thinking may help them be agents of change in their own lives and the lives of others.
- It works better in some disciplines than others - math, science, social studies, English...
- I believe SD should be a part of every algebra, pre-calculus, and calculus course. High school students can build these models and it gives them access to more realistic applications of mathematics.

Next 25 Years in Education

Administrators

- I can't say enough about how wonderful the Waters Foundation is in regards to the quality of professional development for our teachers. It is through the Waters Foundation training that I am getting ST strategies/tools into the hands of teachers! Joan Yates is our trainer, and she is amazing!

Others

- I've been and seen sd st no for 22 yrs. I thought back then 1pyrs tops for sd to be integrated into curricula. / My initial conditions were biased by enthusiasm. / I see now PISA test 2015 HAD A MODEL! Yay! / My hope is now hope that sd st will be entirely embedded within curriculum within another ten. / About 20 - 2000 years late imo.
- Please keep up the good work to make this more widely available!
- actively working on integrating ST/SD in curriculum framework for 4-year program
- Still very new to those who don't understand its value - making examples of materials available is key to acceptance.
- There is some establishments in certain fields that are now obsolete, Therefore, we need to get rid of them. i.e / Michael Porter theories about Competitive Strategy, Competitive Advantage. They were very useful when Demand was greater than Supply, but not nowadays when it is the other way around. / / As we apply ST habits, we need to use new strategies according to the habit of Changing the Perspectives to Increase Understanding. i.e. the competitive weaknesses can not be improved, that is why they are in fact weaknesses. We need to focus on our advantages and try to improved them all the time.
- I'm planning a systems thinking course for 5000 environment and sustainability teachers