Our mission is to develop Systems Citizens in K-12 education who use Systems Thinking and System Dynamics to meet the interconnected challenges that face them at personal, community, and global levels.

www.clexchange.org

Introducing System Dynamics and Systems Thinking to a School (or Children) Near You

A packet of materials designed to help those conversant with system dynamics become involved with the education of students ages 3-19

For more information, conversation or help:

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Anne LaVigne (alavigne@pimaregionalsupport.org)
Contents of this packet

1. Introduction
   These are useful to hand out to interested educators and citizen champions. It incorporates explanations of how ST/SD address the Common Core State Standards as well as the STEM process standards, both preeminent concerns of educators currently. If you need nicely printed copies – contact the CLE.

3. CLE Booklist with pictures and descriptions

4. List of resources including resources, books and articles from the Creative Learning Exchange and other places

5. Characteristics of Complex Systems description

6. Habits page – An illustrated list of the Habits of a Systems Thinker from the Waters Foundation, Systems Thinking in Schools Project

7. Indicators of readiness for schools and districts put together by the experienced mentors from the Systems Thinking in Schools Project of the Waters Foundation

Suggested Creative Learning Exchange Materials for your own perusal and for teachers and schools:

- System Dynamics Apps
- Making Thinking Visible – YouTube
- Shape of Change including Stocks and Flows
- Dollars and Sense: Stay in the Black, Spending and Saving
- Communicating Critical Thinking: Visual Tools for Student Projects
- Model Mysteries
- Systems in Motion
- Coming soon: Splash!
I. Introduction

There are many paths for advocating system dynamics in the world, but none of them has the potential that engaging our youth promises. You, as a knowledgeable SD practitioner, could help interest and inspire the decision makers of tomorrow in several ways. In this introduction, we will briefly show you two:

- Using your own SD tools and principles with your own children; and
- Interesting and encouraging educators in your local area to use ST/SD.

We cannot stress enough that if you have specific questions about any of this material, shoot us an e-mail or give us a call here at the Creative Learning Exchange. (Lees Stuntz (stuntzln@clexchange.org, 978-635-9797 or Anne LaVigne (anne.lavigne@schools.pima.gov))

II. Talk to your own children and help them learn the power of using systems thinking and system dynamics

Starting with your own children when they are young is as easy as reading them The Lorax by Dr. Seuss. (See the lessons on The Lorax on the CLE website.) Linda Booth Sweeney’s books, When a Butterfly Sneeze and Connected Wisdom, offer many suggestions and stories that have “systems” lessons embedded within them. The critical thing about introducing some of these concepts to your kids is to talk with them after reading the stories about the connections, the feedback loops, and the stocks and flows. You can start them out very early on behavior-over-time graphs. Any system dynamics facilitator knows how imperative a good debrief is. Children are no different.

In recent years, the CLE has added a number of visual and interactive tools to its website:
• A series of little videos on the CLE YouTube Channel entitled *Making Thinking Visible* that introduce the standard beginning tools of systems thinking and system dynamics. [http://www.clexchange.org/resources/videos.aspx](http://www.clexchange.org/resources/videos.aspx)

• Four small engaging interactive free apps for mobile devices to start students learning the lessons of system dynamics modeling. [http://www.clexchange.org/curriculum/apps/](http://www.clexchange.org/curriculum/apps/)

• COMING SOON: **Splash!** an engaging free app that combines system dynamics modeling with liquid physics and visual math.

The same materials that teachers use starting out with students are good resources. The “In and Out Game” in the *Shape of Change* is a great way to get a group of kids interested in the concepts of stocks and flows. *The Lorax* can be used effectively to discuss reinforcing feedback as well as stocks and flows. The “Getting Started” page on the website has great tools for not only for teachers, but also for parents. [http://www.clexchange.org/gettingstarted/](http://www.clexchange.org/gettingstarted/)

For older children, the other *Shape of Change* lessons, *Dollars and Sense: Stay in the Black, Saving and Spending, Dollars and Sense II: Our Interest in Interest* lessons, as well as the Oscillation Simulations and Lessons from the Characteristics of Complex Systems Project would be good introductions for kids. There are lessons for all ages.

Our book *Model Mysteries* is a terrific self-paced introduction to system dynamics modeling for students in grades 6-12.

**III. Get your local school, teacher and school district involved in using systems thinking and system dynamics to foster critical thinking tools in the classroom (and in the organization)**

All of the materials listed above are excellent resources for teachers. The CLE Introductory Packet has a number of pertinent articles about the introduction of ST/SD into schools. We now have over 25 years experience about what works and what doesn’t, but, ultimately, if you are interested and committed, you will want to find your own path.
Some of the materials in the CLE Introductory Packet are appropriate to whet teachers’ appetites, but often it is a lesson or a book, with some help using it, that is the key. We have found that teachers and students can readily learn and produce behavior-over-time graphs in a relatively short period of time.

At any point in the process, we at the CLE are happy to talk with you and give you a few hints of what we have found that works. Here is a list of a multitude of ways to get started.

- Talk to the educators you know, your children’s teachers and principal, and give them materials.
- Meet with the principal and/or teacher at your child’s school and ask about strategies used to foster thinking about complex systems being studied. Offer to meet with any interested teachers.
- Attend a local school board meeting.
- Create an internship opportunity for interested local high school students.
- Sponsor a system dynamics club at a local school district or youth organization.
- Offer a short workshop for teachers on using one or more tools.
- Sponsor a teacher to attend a conference or workshop for integrating ST/SD into their instruction.
- Help a teacher build a model of a system of interest.
- Help teachers identify age-appropriate resources that are already available.
- Participate in K-12 ST/SD conferences and workshops.
- Offer to coach educators.
- Facilitate an administrative team using ST/SD tools, Group Model Building.
- Work with your own children.
- Encourage your students to work with K-12 teachers, students.
- Give talks introducing systems thinking in education.
• Advocate for a systems thinking in K-12 role in your institution’s vision of community citizenship
• Offer to teach courses in systems thinking to groups of teachers, students, and community members.
• Become a systems thinking voice on non-profit boards.
• See if you can be involved in committees writing state or local education plans.
• Volunteer in after-school programs in K-12 and introduce ST/SD tools and principles.

We are sure there are others not listed. We hope you will find them and share them with us and others. Don’t forget that we would enjoy hearing from you and creating a community that goes forward together to get these critical skills and habits of thought to our younger generation.
About The Creative Learning Exchange

Our Mission
To develop Systems Citizens in K-12 education who use systems thinking, system dynamics, and an active, learner-centered approach to meet the interconnected challenges that face them at personal, community, and global levels.

The Creative Learning Exchange (CLE)
The Creative Learning Exchange was founded as a non-profit in 1991 to encourage an active, learner-centered process of discovery for K-12 students that engages in meaningful, real-world problem solving through the mastery of systems thinking and system dynamics modeling.

Since its inception, the CLE has worked to encourage teachers and educators to use systems thinking and system dynamics in classrooms and schools throughout the United States as well as internationally.

The CLE has done this through its website that offers free curriculum, its products that include books and games that promote systems thinking, and a biennial conference to help educators and students learn and utilize systems thinking and system dynamics in the classroom and the school organization.

How to be part of the CLE network
• Register with the CLE online at www.clexchange.org.
• You will start to get our quarterly newsletter, *The Exchange*, as well as email notifications of new curricula and upcoming events. These materials are available for download from the web.
• Browse and download our free materials.
• All of the curricula and other materials are in Adobe PDF format and the models are in STELLA®. A run-time version of STELLA is available from isee systems: www.iseesystems.com. Our newer curricula also has simulations which can be run directly from the CLE website.
• Join the CLE K-12SD listserve from the CLE website to make connections, find resources, and ask questions of experienced teachers and world-class system dynamics experts.

— Visual Tools of System Dynamics/Systems Thinking (SD/ST) —
The most effective use of these tools is to utilize more than one in each application.

• Behavior-over-Time Graphs
  Show behavior of one or more elements of a system over a period of time, using line graphs.

• Feedback Diagrams
  Use words and arrows to map how elements of a system interact and affect each other.

• Stock and Flow Diagrams
  Draw stocks (accumulations of quantities) and flows (factors that change the stocks) to show the structure of a system.

• Computer Models
  Use equations and functions to simulate or replicate behaviors in a system.

Publications available from the Creative Learning Exchange

The Shape of Change, Including Stocks and Flows contains lessons with a variety of systems thinking tools that engage students in classroom activities that help them understand not only what but why things change over time.

This pair of books shows the effective use of systems tools to improve the capacity to think critically. *Communicating Critical Thinking: Visual Tools for Student Projects* is a short, practical guide for students and teachers to use for integration in the classroom. *Critical Thinking Using Systems Thinking & Dynamic Modeling* is a more in-depth guide to the subject.

Dollars and Sense challenges students to use systems thinking and mathematical tools to develop a realistic understanding of the dynamics of personal finance. *Dollars and Sense II* uses engaging computer simulations to teach the effects of saving, interest and spending.

Characteristics of Complex Systems—Oscillating Systems
Age-grouped for ease of use, each book contains interdisciplinary lessons with accompanying free, online simulations with explicit connections to curriculum content standards and critical thinking skills.

*…that School in Tucson is a longitudinal study of systems thinking in K-12 education. Thirteen years ago, middle school students and their faculty in Tucson, AZ, pioneered a revolutionary new approach to learning—using systems thinking tools to engage in collaborative, real-world problem solving that honed their critical thinking skills.*

Healthy Chickens, Healthy Pastures is a game that has been created to help students think deliberately about living systems in a farm setting and give them a mental framework to take home and apply in other contexts.

Systems Thinking and Dynamic Modeling Conference
The CLE hosts a biennial conference on systems thinking and dynamic modeling. Speakers and presenters are teachers, administrators, and experts in system dynamics. For more information, go to www.clexchange.org or e-mail info@clexchange.org.

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System Dynamics/Systems Thinking and the Common Core, STEM and New Generation Science Standards

Effectively addressing the Common Core State Standards, New Generation Science Standards and STEM strategies requires more than K–12 education as usual. One of the biggest challenges of STEM curricula and, in fact, all curricula, is creating opportunities for students to gain experience and practice in the process of critical thinking. The utilization of System Dynamics/Systems Thinking (SD/ST) offers a unique methodology for addressing these higher-order thinking skills in a way that creates a framework to gain knowledge, as well as the tools to communicate thought.

SD/ST offers an integrated way of thinking, in practical and useful ways, about the complex, interconnected systems that surround us, and how they change over time.

### Common Core Standards

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<tr>
<td><strong>Reading</strong>—develop staircase of increasing complexity to build comprehension in a diverse array of content.</td>
<td><strong>Dealing with Complexity</strong>—SD helps students understand behavior systematically, seeing the big picture, with graphic tools for representing behavior.</td>
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<td><strong>Writing</strong>—express logical arguments and opinions, using research skills frequently.</td>
<td><strong>Clarity</strong>—SD diagrams and models create visual examples that can be easily understood by readers.</td>
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<td><strong>Speaking and Listening</strong>—employ a mix of one-on-one, small group, and whole class structures, emphasizing collaboration and problem solving.</td>
<td><strong>Learner-Centered Learning</strong>—students using SD tools effectively work in teams to solve problems that arise from their studies.</td>
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<td><strong>Language</strong>—build a precise and varied repertoire of vocabulary.</td>
<td><strong>Precision of Language</strong>—describing systems requires concise and accurate wording.</td>
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<td><strong>Science, History and Social Studies</strong>—apply English language arts skills across the curriculum to promote content area literacy.</td>
<td><strong>Interdisciplinary Learning</strong>—students learn to recognize generic structures that occur across their curriculum. Understanding feedback provides insight into social issues and policies.</td>
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<tr>
<td><strong>Media and Technology</strong>—integrate 21st Century skills throughout the curriculum, and use modern applications for varying assumptions, exploring consequences, and comparing predictions with data.</td>
<td><strong>Computer Modeling</strong>—from upper elementary grades through high school, students can use software to build simulations of situations in many content areas. SD tools and models give students the ability to change assumptions, compare predictions and explore consequences in powerful ways.</td>
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### Mathematics

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<tr>
<td><strong>K-5 Math</strong>—build a solid foundation in whole numbers, computation, fractions and decimals, negative numbers, and geometry. Emphasize hands-on learning, to continue through upper grades.</td>
<td><strong>Representing Data</strong>—graphing data over time requires students to use a wide array of math skills. Simulations, experiments, and other activities where data are analyzed reinforce quantitative thinking.</td>
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<td><strong>Mathematical Reasoning</strong>—build solid conceptual understanding, as well as procedural skills. Enable 8th graders to understand algebra with an emphasis on linear expressions and functions.</td>
<td><strong>Quantitative Thinking</strong>—SD promotes dynamic understanding through stock and flow thinking. Tools are quantities that change because of inflows, or rates of change. SD modeling creates a visual framework to understand mathematical functions.</td>
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<td><strong>Mathematical Application</strong>—guide students to apply math reasoning to real-world issues and challenges, and use math in novel situations.</td>
<td><strong>Generic Structures</strong>—students learn to transfer insights across curriculum areas, connecting diverse topics by systemic structures.</td>
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<td><strong>Mathematical Modeling</strong>—use modeling to link classroom experience to empirical situations, leading to better understanding and decision-making.</td>
<td><strong>Mathematical Modeling</strong>—using readily accessible, powerful software, students can model sophisticated situations and run simulations to test assumptions, create alternate scenarios and explore consequences.</td>
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<td><strong>Applied Modeling</strong>—model quantities and their relationships in physical, economic, public policy, social and everyday situations.</td>
<td><strong>Applied Modeling</strong>—students can build and use models that allow &quot;what if&quot; simulations in most curriculum areas.</td>
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### System Dynamics/Systems Thinking (SD/ST) Tools and Learning Strategies to Build Science, Technology, Engineering, and Math Excellence

- **Map the structure of systems**
  - Use computer models to simulate varieties of scenarios and ask “what if …?”
  - Use, recognize, and analyze models

- **Describe systems concisely and accurately with words and diagrams**
  - Use a variety of graphic tools

- **Analyze and graph data over time**

- **Plan, Understand, Act**

- **Gain knowledge of contemporary issues and appreciate personal and social context**

- **Understand and apply feedback**

- **Simulate and model**

- **Understand multiple content areas**

- **Track change over time to question how and why things change**

- **Build models that include social and personal issues**

- **Recognize generic structures and see recurring patterns and structures in different situations**

- **Identify leverage through understanding of system structure and apply insights across curriculum areas**

- **Investigate how elements change over time in order to focus on patterns and trends**

- **Work in teams on problem solving**

- **Effective STEM Education**

- **Use technology and math, and apply abstract and quantitative reasoning**

- **Focus on inquiry and investigation while working in teams**

- **Describe systems concisely and accurately with words and diagrams**

- **Use, recognize, and analyze models**

- **Communicate effectively**

- **Learn and apply insights across multiple content areas**

- **Understand the structure of systems and how to apply insights across curriculum areas**

- **Recognize generic structures and see recurring patterns and structures in different situations**

- **Identify leverage through understanding of system structure and apply insights across curriculum areas**

- **Investigate how elements change over time in order to focus on patterns and trends**

- **Work in teams on problem solving**
Model Mysteries
If you like mysteries and creating computer models, this book is for you. Students, use it independently or work with a group. Teachers, share it with students to complete a guided or independent study. The book has 6 chapters, each with a new mystery to solve. Each chapter has a number of similar stories to try. $21.50

Systems in Motion: Exploring Complexity through an Interdisciplinary Lens Levels A, B, and C
The lessons in this series of three books, Levels A, B, and C are age-grouped for ease of use. Each book contains interdisciplinary lessons with accompanying free, online simulations that have explicit connections to curriculum content standards and to critical thinking skills. Background information for all the lessons is available at http://www.clexchange.org.
A $19.50
B $24.50 Set of 3
C $28.50 $60.00

Healthy Chickens, Healthy Pastures is a game created to help students think deliberately about living systems in a farm setting and give them a mental framework to take home and apply in other contexts. $20.50

Critical Thinking Using Systems Thinking & Dynamic Modeling correlates critical thinking skills with the use of systems thinking and dynamic modeling. It expands upon how to use the tools of systems thinking and dynamic modeling to improve critical thinking, covering the why and the how of using systems thinking and dynamic modeling in education. $20.00

Tracing Connections collects the experiences and thoughts of practitioners from education, business, public policy, and research to present the powerful applicability of systems thinking. $29.00 from isee systems.com

For more information, email info@clexchange.org

Available from the CLE website: clexchange.org

The Shape of Change, Including Stocks and Flows contains lessons with a variety of systems thinking tools that engage students in classroom activities that help them understand not only what but why things change over time. $29.50

Dollars and Sense II: Our Interest in Interest uses engaging computer simulations to teach managing personal finances to students in middle and high school. Learner-directed learning and systems thinking combine to make the concepts of saving, interest, and spending come alive. $29.50

...that School in Tucson is a longitudinal study of systems thinking in K-12 education. Thirteen years ago, middle school students and their faculty in Tucson, AZ, pioneered a revolutionary new approach to learning—using systems thinking tools to engage in collaborative, real-world problem solving that honed their critical thinking skills. DVD and booklet. $35.00
Characteristics of Complex Systems

What is the K-12 Education Project?

Led by a partnership between MIT Professor Emeritus Jay W. Forrester and the Creative Learning Exchange (CLE), the goal of the project is to create online curriculum materials for ages five and above that will illustrate the characteristics of complex systems.

Project Goals

The long-term goal of the project is to help our audience understand the nature of complex social systems – why do such systems resist policy changes? Why are short-term and long-term responses to corrective action often at odds with each other? How can leverage points be applied to bring about desirable change in social systems?

An abstract level of understanding with regards to social systems will help prepare future citizens to actively shape their society.

What are the characteristics?

Complex systems do not always act the way that we would intuitively expect them too. By applying common characteristics to complex systems, understanding of these systems becomes easier.

- Cause and effect are not closely related in time or space.
- Action is often ineffective due to application of low-leverage policies.
- High-leverage policies are difficult to apply correctly.
- The cause of the problem is within the system.
- Collapsing goals results in a downward spiral.
- Conflicts arise between short-term and long-term goals.
- Burdens are shifted to the intervener.

What are the available resources?

The lessons and simulations initially produced are based upon the fourth characteristic of complex systems, the cause of the problem is within the system. Simulations and lessons are age appropriate, easy to use, easy to access online, free, and aligned with national K-12 standards.

Five interdisciplinary areas are part of this series of lessons.
- Spring Dynamics
- Interpersonal Relationships
- Predator/Prey Dynamics
- Burnout
- Economics of Commodities

In addition, all CLE lessons are now categorized to include connections to all seven characteristics.
Habits of a Systems Thinker

- Seeks to understand the big picture
- Observes how elements within systems change over time, generating patterns and trends
- Recognizes that a system’s structure generates its behavior
- Identifies the circular nature of complex cause and effect relationships
- Makes meaningful connections within and between systems
- Changes perspectives to increase understanding
- Surfaces and tests assumptions
- Considers an issue fully and resists the urge to come to a quick conclusion
- Considers how mental models affect current reality and the future
- Uses understanding of system structure to identify possible leverage actions
- Considers short-term, long-term and unintended consequences of actions
- Pays attention to accumulations and their rates of change
- Recognizes the impact of time delays when exploring cause and effect relationships
- Checks results and changes actions if needed: “successive approximation”
Systems thinking is a unique innovation with tremendous potential to improve educational opportunities for all children. However, we know that the application of systems thinking in schools is most effective when other conditions in the school complement its implementation. The words below are an attempt to describe the optimal school culture in which to nurture systems thinking. **There is a definite danger in interpreting these indicators as a checklist, all needing to be present in order for a systems thinking in schools initiative to prosper, which is not the case.** Various combinations of these descriptors have been present to varied degrees in successful demonstration sites.

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<td>Learner-centered learning</td>
<td>Teachers should be open to an active role by students in the learning process. Further, these schools show evidence of meaningful, relevant, interdisciplinary curriculum and project-based approaches. In these schools the teacher often assumes the role of coach and advisor. Teachers whose pedagogy is heavily focused on lecture or teacher-directed methods will have more difficulty adapting to a systems thinking approach.</td>
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<td>Evidence of inquiry in classroom practice</td>
<td>The use of inquiry or a constructivist approach to learning is highly complementary to a systems thinking approach. The use of systems thinking in the classroom increases quickly when teachers are able to use student responses and questions in their systems lessons. Students who feel some ownership for their own learning and who have experience exploring topics of personal interest are applying skills that will be useful in learning more about systems thinking.</td>
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<td>Varied measures of student achievement</td>
<td>Demonstration site teachers and administrators actively seek and develop measures of student achievement that identify success indicators beyond the scope of traditional standardized tests. Collaborative action research has successfully utilized and developed alternative measures.</td>
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<td>Commitment to life-long learning</td>
<td>All staff and students exemplify this commitment. Life-long learners are intellectually curious, ask questions, pursue topics of interest and openly express their desire to learn.</td>
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<tr>
<td>A culture of teaming and openness to learning from one another</td>
<td>Teachers need to be willing to learn from and along with their colleagues in the application of systems thinking to classroom learning. Likewise, administrators who are effective in supporting the implementation of systems thinking in their buildings must also be willing to learn from their staff. The use of site-based decision making or evidence of teacher leadership in a building may indicate this willingness to learn collectively. Teachers who have a history of learning together either through teacher-led professional development or frequent collaborations to review student work show evidence of team learning.</td>
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<td><em>Involvement by the whole staff, where staff includes certified, classified, and administrative personnel, preferably at the school and district level</em></td>
<td>Full support by all stakeholders is particularly important to the sustainability of the innovation. Teacher commitment to applying the tools of systems thinking is particularly helpful. It has been the experience of the project that when teachers are forced to attend the training their success is diminished. Some teachers have been very effective as “lone rangers” working to build their personal systems thinking capacity without the benefit of a team, but this is clearly not optimal. A supportive administrator, one who brings the idea to staff and then finds ways to elicit their support, or one who is willing to support staff members and participate in the learning, produces the most effective results.</td>
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<td><em>Baseline teacher competence</em></td>
<td>The application of systems thinking to daily instruction can be complex and is best undertaken by teachers who have other essential components of planning, assessment, instruction and management in place.</td>
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<td><em>Evidence of self-starting in the use of systems thinking in classroom and organization (&quot;moving train&quot;)</em></td>
<td>It is highly desirable that schools evidence some familiarity or interest in the systems thinking approach through prior use or experimentation with the tools organizationally or instructionally.</td>
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<tr>
<td><em>A whole-community approach</em></td>
<td>Sustainability of any innovation requires the support of the community. Any school system desiring to comprehensively apply the tools and habits of systems thinking must have a very specific plan for engaging the entire community, including parents and the business community. When the community is enrolled, the innovation tends to flourish even when school or district leadership transitions occur.</td>
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<tr>
<td><em>Student involvement in organizations outside of school, e.g. government, community</em></td>
<td>Schools ready for systems thinking are schools that encourage student voice in a variety of ways. Enthusiastic students will be a hallmark of this indicator.</td>
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