The CREATIVE LEARNING Exchange
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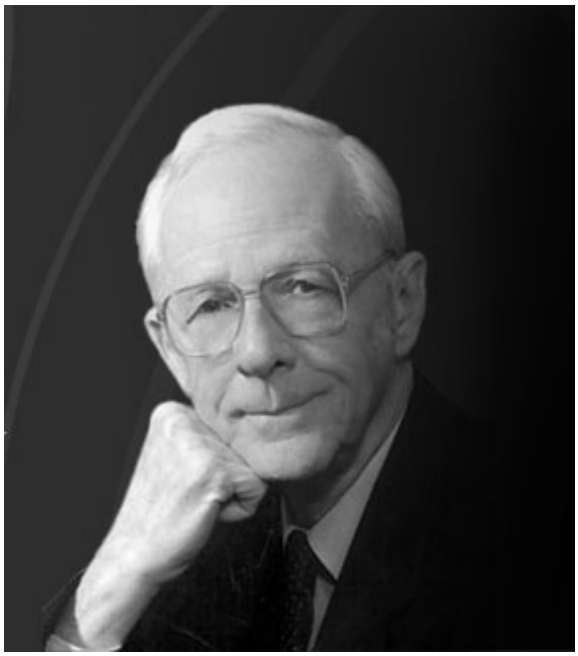
Remembering Jay Forrester

July 14, 1918 –November 16, 2016

by Ralph Brauer

Concord. The name reverberates in the American mind with the sharp crack of unexpected gunshots, volleys of regeneration, signaling a change in direction. Warning shots aim at the status quo, pulled by the itchy trigger finger of the future, driven by fractious impertinence. I was reminded of that at a place called Author's Ridge. There lie the tombstones of more literary talent per square foot than anywhere else: Ralph Waldo Emerson, Henry David Thoreau, Louisa May Alcott, Nathaniel Hawthorne, who lived here much of his life, but whose body lies in English soil. Further down the road lies the famous "rude bridge" Emerson saluted as the place *"embattled farmers stood. And fired the shot heard round the world."*

It was for a revolution I came to Concord in 2012, but it was not Emerson's nor the one so grandly celebrated by the town on the upcoming Fourth, but one led by a tall, lanky, white-haired former Nebraska prairie dweller named Jay Forrester. This revolution bears the title of system dynamics, words that promise to be as world shaking as the other ones that rocked Concord. They herald a change of perspective as radical as Emerson's transcendentalism.



Tall and rangy and looking as though he could still pitch a few bales of Nebraska hay, the founder of the movement was someone whose mind worked on a different level. Any conversation with him sooner or later elicited a connection so thought-provoking it left you stunned. A friend said one of the first times he met Jay Forrester was during the social hour of a conference, as the two of them were sitting watching the new craze of western line-dancing. Forrester turned to him and matter-of-factly remarked, "Calculus is an artificial construct. None of its concepts really exist in nature." I am still pondering the meanings of that observation.

For all his sheer intellectual power, Forrester had the approachable manner of someone who grew up on the margins of rural America. He was the only major thinker/founder of a discipline who sat in on papers delivered by high school teachers and then had lunch with them afterwards. Yet, as generations of MIT graduate students will tell you, he had little use for those whose thinking is sloppy, lazy or ideological. MIT professor John Sterman, who has known several Nobel Prize winners, says Forrester's mind was the most brilliant he has known.

Besides the fact that he may have been the most deserving person not to receive a Nobel, that he helped to design one of the world's first useable computers, that he sits in the inventors Hall of Fame as the originator of the core memory process, Forrester is significant because more than anyone else he sat astride the old age and the new. A certified founder of what is termed the Information Age, the field he created, system dynamics, may be the closest thing we have to a vision of what the intellectual order of a post-Information Age world will be.

***Jay Forrester** continued on page 4*

THIS ISSUE AT A GLANCE

Remembering Jay Forrester	1
Splash! New SD Software	2
System Dynamics Apps	3
DynamiQue*ST* - March 17, 2017	5

EDITORIAL

As usual, we are always amazed at the weather in the winter in New England. Going from sub-zero temperatures to balmy 55 degrees and back again seems to be the norm. I do worry about our poor confused plants!

This issue pays tribute to the founder of the CLE and the discipline of system dynamics, Jay Forrester. Jay was a good friend and inspiration to us all. His guidance and his high standards will be missed.

Ralph Brauer, an accomplished author, has been a friend of system dynamics in K- 12 education for decades. He was originally inspired by Jay's vision and has worked over the years to bring the concepts of system dynamics to a broader audience. We apppreciate his sharing his memories of Jay with us.

Throughout this fall, the CLE has been working on a couple of interesting projects with BTN, a group from Singapore. Ninad Jagdish and his team bring both expertise in system dynamics as well as in graphic design and app creation. We are very excited to be working with such a competent group.

The product of one of these collaborations is the set of four apps showcasing simple models, described on page 3 with links to the webpage for downloading. This group of four will be expanded in the next few months.

The second is a bit more extensive. Some of us have been working with BTN to come up with a concept for simple system dynamics modeling that creates an experiential bridge between physical 3-D modeling environment and the virtual 2-D modeling environment of the current extremely capable software. We are looking for funding for the next phase. Check out the page on the CLE website for more information. We would love comments, and most of all, help finding other partners to make this a reality.

Take care,
Lees Stuntz
(stuntzln@clexchange.org)

A New Kind of System Dynamics Software

What is Splash!?

Liquid Physics + System Dynamics = Splash!

Whether it's managing your health, planning your retirement or addressing climate change, System Dynamics (SD) can help us tackle the wide variety of dynamic problems we find in the world around us.

There are several software products available in the market to create system dynamics models. These highly capable and flexible tools are often designed for advanced users and professionals. But they can end up being intimidating and boring for those who are just starting to learn system dynamics.

There is an evident need for a simple modeling software that's designed with beginners in mind – something that middle and high school students might use to learn system dynamics. If this tool existed, it would make system dynamics accessible to a much broader audience and help catalyze its use.

Splash! is exactly such a software. Designed primarily for tablets and mobile devices, Splash! combines liquid physics simulations with system dynamics in a way that emphasizes fun, delight, and ease-of-use as much as it does the core principles of system dynamics.

Learn more in the Splash Design Document.

Invest in Splash!

The Splash team is currently looking for funding partners to actualize the vision of this software. Contact Lees Stuntz at the CLE for more information.

NEW!! System Dynamics Apps!

The CLE is excited to announce the development of new system dynamics apps. These simple, fun and engaging apps are ready for use on phones, tablets, or Chromebooks. They are quick to use and create excellent insight for all ages using system dynamics models.

Explore today!

These apps are based on the *Demo Dozen* models created by Jeff Potash and John Heinbokel and developed in a collaboration with the Creative Learning Exchange, the Center for Interdisciplinary Excellence in System Dynamics, and BTN.

When is it better to invest in retirement? Is it safe to leave that sandwich out of the refrigerator? Can you create a stable population?

Learn more and download these new CLE apps.

POPULATION PLANNER

In *Population Planner* you will see the simplest of population models. Experiment with the model, change the average birth and death rates to see whether the population grows or shrinks.

RETIRE RICH

Retire Rich is a simple system dynamics model for retirement planning. Experiment with the model to see how your annual savings, the duration over which you save, and the interest you earn determine the size of your retirement fund.

BACTERIA SANDWICH

Bacteria Sandwich presents a simple system dynamics model on bacterial growth. Experiment with the model to see how the number of bacteria in food can rise exponentially, and how cooking food helps keep it safe.

'I' IN INFLATION

'I' in Inflation presents a simple system dynamics model on rising prices. Experiment with the model to see how your purchasing power can go up or down, based on the rate of inflation.

We are very enthusiastic about this new and engaging way to get both students and adults interested in the insights gained by thinking through problems using a system dynamics methodology. We would love to hear from anyone who uses the apps to tell us how you are using them in and out of your classrooms, your advisories, or with your children.

Remembering Jay Forrester

continued from page 1

Forrester was one of the few people whose life story was a cultural and intellectual history that spanned three distinct worlds, three centuries. To know Forrester's biography is to know what we were, what we are and what we may be becoming. It would not be too much of an exaggeration to say Jay Forester was born two centuries ago. The Nebraska ranch country he spent his childhood in, owed more to the 1800s than it did to the Twentieth Century. The best portrait I know of those times is Terrence Malik's brilliant film, *Days of Heaven*. In the film, as in Forrester's life, machines were just making an impact. They dominate parts of the film like great, primitive beasts, wading through the crops with a saurian plod, the rhythm of their engines a heartbeat that smothers the sounds of the prairie, their giant leather drive belts moving like flickering tongues. Malik heightens his message by alternating sequences of the harvest with stunning shots of nature: shocks of wheat sparkling in the morning sun, bees flitting from flower to flower and acres of untouched grasses undulating like ocean waves in the wind.

Forrester grew up unafraid of these monsters on a ranch his father homesteaded in the Nebraska sand hills. It is a rough country in which to make a living, especially during the 1920s, when the Depression had already begun in rural America. They had no electricity, no phone, no television and for company there were the thirty-five people who lived in the nearby towns. Like many rural boys—the ones who built the automobile, the airplane, the reaper—Forrester was a tinkerer who knew how to tame unruly machines as surely as a wrangler with an angry stallion. Forrester studied their gears and pulleys, taking them apart and putting them together again until he understood how they worked. He passed from being able to take things apart to jerry-rigging repairs for machines for whom a repair was many miles and many dollars away. Then he began creating new machines. It was a talent possessed by only a few men with well-calloused hands, but a miracle in someone who was just a youngster. He could play a machine the way the youthful Mozart could improvise on the piano with his eyes closed. He devised a mechanism that controlled where the mowing machine dumped its grass. He electrified the screen door, turning it into a bug zapper. In the basement he developed his own photographs. He prowled junkyards for parts, using them to construct a Tesla coil that produced six inch lightning bolts. He built a power plant for his mother and father.

His innate curiosity was encouraged by parents who fed him books and magazines. Forrester was a firm believer in what educators term learner-centered learning—learning that allows students to discover and explore, much as he did. His parents, he told an interviewer, treated his tinkering "as if it were worthwhile and important." He would take the lessons from these early experiments with him throughout his life. The key lesson has the humility of genius: "through trying things, failing, trying things and succeeding you get your own calibration as to what you can do and can't." In those words Forrester revealed his passion. Einstein spent his life searching for God. Leonardo had an alchemist's desire to pin down the order of the universe. Forrester did not seek The Answer so much as he sought The Question. He frequently pointed out there are no straight lines in nature, but, instead, slopes one did not so much define as reach accommodation with, the way an Olympic medalist seeks that perfect run on precipices most of us would have trouble walking.

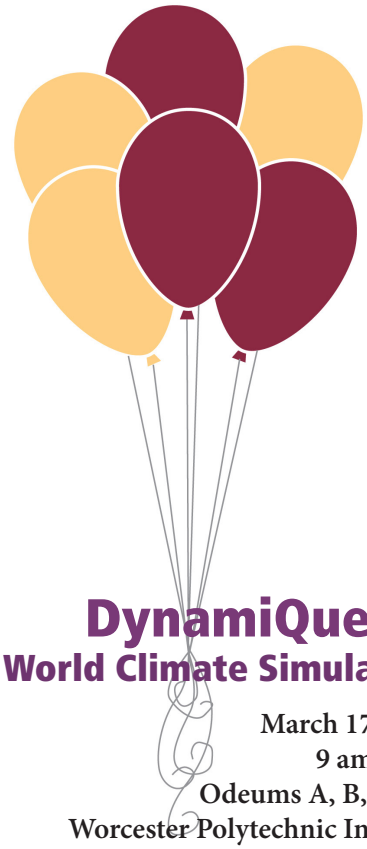
After receiving an engineering degree from the University of Nebraska in the thick of the Depression (think of not only the sacrifice but the foresight and dedication such an effort required), he found himself in the midst of a war. He became part of a small group of young geniuses that worked on some of the most crucial projects of World War II, all involving early applications of computer technology. One of them, a fellow Nebraskan named Bill Norris worked on cracking the Japanese code, then went on to found the computer company, Control Data. He once told me he thought Forrester was the smartest of the bunch.

It is hard not to walk anywhere in Concord without coming face to face with war. In the town square stands a huge monument to the Civil War, dedicated by Emerson. Signs point to cemeteries with Revolutionary War dead and give directions to the field where this country was born. War dead hover over Concord like interrogating spectres, asking us to remember the meaning of their deaths. You come upon them unexpectedly. Staring at you is William Forbes Emerson, Lt. 604 Bomb Squadron, Air Corps, US Army, July 27, 1943, February 14, 1944.

I remember a college teacher's adage that war is a history of technological change. There is, of course, the template of them all, Agincourt, where a small band of English armed with long bows extinguished chivalry in a rain of arrows. The American Revolution in part hinged on the superiority of the

***Jay Forrester** continued on page 6*

DynamiQue*ST*: Simulations for Real Challenges



DynamiQue*ST*:
World Climate Simulation

March 17, 2017
9 am-3 pm
Odeums A, B, and C
Worcester Polytechnic Institute
Worcester, Massachusetts

DynamiQue*ST* is a showcase of the power of simulations and creative student projects that utilize critical thinking skills to analyze complex dynamic systems. ***JOIN US*** to play the World Climate Simulation created at MIT and used internationally to facilitate current world climate negotiations. ***SEE HOW*** systems thinking and system dynamics can elucidate both global issues and curricular content.

What Are the Goals of DynamiQue*ST*?

- Experience the World Climate Simulation, based on systems thinking, and used around the world to understand the issues surrounding climate change.
- Apply practical critical thinking tools to a real-world problem.
- See student projects that embody critical thinking using systems thinking and system dynamics (ST/SD).
- Showcase student work for the wider community.
- Meet students from other communities.
- Have some fun and celebrate with kids!

Who Will Be There?

Students (ages 12-18), teachers, and parents will participate in the simulation and learn to utilize some of the tools of system dynamics and systems thinking to analyze and clearly communicate critical thinking. Coaches will be there to facilitate learning.

How Do I Know if DynamiQue*ST* Will Fit My Students?

Do you and your students want to delve deeper into real-world challenges such as Climate Change? Join us as we do so on March 17! No experience neded! DynamiQue*ST* creates a venue for learning about Climate Change and the tools to help think about it constructively.

Schedule for the Day:

- 9-11:30 World Climate Simulation
- 11:30-12:30 Lunch and appreciating projects from students who use systems thinking and system dynamics tools.
- 1:00-2:30 Debrief of World Climate Simulation using systems thinking tools to create critical thinking and practical approaches.

Who Are the Coaches?

- Professionals well versed in analyzing complex systems using the tools and methods of ST/SD.
- Teachers who have used ST/SD in their classrooms for years.

How Do I Sign Up?

- Check the Creative Learning Exchange website (www.clexchange.org) or email the director, Lees Stuntz. If you are new to systems thinking, get in touch with the CLE. We have both the resources and the willingness to help you get ready for DynamiQue*ST*.
- If your students are already using ST/SD in their work, identify project(s) about topics that change over time. Look at the Rubrics for Projects document on the DynamiQueST section of the CLE website. (http://www.clexchange.org/news/dynamiquest/)
- If you are new to thinking critically about systems and don't have any projects this year, just come and join us to experience the day and mostly enjoy what students can do! For more information, visit DynamiQue*ST*. Download the brochure.

Cost for the day $25 per person, which includes lunch. Bring a full car - $100 for 5 participants!

Remembering Jay Forrester

continued from page 4

American hunting rifle, enabling the New England militias to fight the guerilla style battles that chased the lobsterbacks all the way back to Boston after the Battles of Lexington and Concord. Recently I saw an article, whose source is lost to me, that maintained George Washington made a key move when he had his troops vaccinated for smallpox at Valley Forge. The Civil War saw the debut of the repeating rifle, rifled cannon shot, submarines, ironclad warships and the first true field hospitals. Gatling guns essentially won the Spanish American War. World War I was the first large scale application of blood bank technology and transfusions along with a formidable array of weaponry from fighter planes to tanks.

Then came WWII. The party line holds this conflict spawned the atomic age, but the true technological revolution of that war was the computer. Jay Forrester came into the war from what was known as the servomechanism laboratory at MIT, an engineering think tank directed by a charismatic and forward-looking leader named Gordon Brown. It is easy to see how the young tinkerer might have ended up there, for servomechanisms is a fancy term for the controls that regulate the actions of machines. Among the projects he worked on was improving how to better control guns that protected ships from aircraft that moved faster than a gunner's reflexes. Forrester also headed a project to build a flight simulator. Expanding on an idea from colleague Perry Crawford, Forrester proposed the simulator be built using computers. That led to Whirlwind, the first digital computer to run in real time.

Reading this history reminds me of Concord, because the early computer designers in the United States and Britain worked closely together, knew one another and probably talked daily with the same electricity that powered the conversations of Ralph Waldo and Henry David. If one were to make a movie of this (and someone should), the late James Stewart would make a perfect Forrester. Not the James Stewart of *It's a Wonderful Life*, but the edgier Stewart of the Hitchcock mysteries, steely, determined, even at times a bit bristly to get at the truth of matters.

Whirlwind presented serious engineering problems, which caused some to doubt if the device was practical. Like all early computers, Whirlwind was a behemoth. It was two stories high with over 3000 electrostatic tubes and 8,300 crystal diodes that generated enough heat to require a special air conditioning unit. The Achilles heel of the device was the electrostatic tubes, which had a life measured in the hundreds of hours. This meant that at any time a few could flicker out and die, potentially shutting down the whole system. Forrester devised two solutions to this problem. The first was to create better memory to preserve the results of the calculations. The second was to figure out a way to program the device so even if tubes did fail, the computer would keep working.

This was the beginning of system dynamics. Forrester had to understand how information flowed through the system of tubes and diodes, so that the redundancy needed to make Whirlwind work even while some of its parts were dying was not so cumbersome as to make the computer useless. The concept of focusing on the whole is fundamental to engineering. You could not build a bridge or an automobile engine without it. Forrester's genius was in perceiving the whole not as a bunch of parts but as a system; to focus on interrelationships not pieces. It was as revolutionary a change in perspective as what Galileo saw through his telescope. Donella Meadows' comment about systems thinking captures the essence of that revolution:

In the systems view the interrelationships are important...You can't understand the essence of a symphony orchestra by looking just at the instruments and the players—it is also the set of relationships that causes it to produce beautiful music. The human body, the nation of Hungary, the ecosystem of a coral reef, are all more than the sum of their parts. As an ancient Sufi sage said, "You think because you understand one you must understand two because one and one make two. You must also understand ***and****."*

It is in the ***and*** that Jay Forrester lived.

Whirlwind went on to play an important role in America's next war—the Cold War. The project was nearly scrapped in the late 1940s because of questions about its cost and usefulness. Then came intelligence reports that the Soviet Union had developed bombers that could reach the United States. In 1950 a special Defense Department Committee recommended developing an air defense system that could track flight paths and help identify hostile aircraft. The Committee was farsighted enough to see that such a system would demand a computer to process and coordinate the huge volume of information and to do it quickly enough to give defense forces time to head of the threat. The result was SAGE (Semi-Automated Ground Control Environment) which consisted of a network of computers built by a company named International Business Machines.

Forrester became head of the project which was fully implemented in 1963 with 73 information nodes spread across North America.

Forrester moved over to the Sloan School at MIT, where he created system dynamics as a way of understanding the behavior of social systems. The discipline he founded has now grown to international status, with thousands of members and sponsors that include a who's who of major corporations. Although this growth has occurred largely off the radar screen of the mainstream media, there have been occasional stories. In the early seventies Forrester wrote an influential paper titled "The Counterintuitive Behavior of Social Systems," that used system dynamics to examine public housing policy and other issues. Many at the time dismissed his conclusion that clustered public housing could make things worse. It took a while for policy makers to catch up to Forrester, but today most of the units of that housing have been destroyed. Not long after that, Forrester and his MIT colleagues did much of the research behind the famous Club of Rome statement on environmental policy and diminishing resources, another prophetic analysis.

In Concord that day, Jay Forrester was helping to spearhead a growing movement in system dynamics—to take its way of thinking to the next generation, to teach it to school children as young as kindergarteners, so they can become the foundation of this new century. Walking the back roads of Concord, prowling the creaking stairways of the Colonial Inn, it occurred to me Concord is a fitting place for system dynamics people to meet, for along with the revolutionary parallel there is an organizational parallel.

The colonists who stood on that wooden bridge in Concord, as the Redcoats mustered on the other side, may not have been able to totally articulate what they were about to do in words as eloquent as Emerson's famous poem, but deep in their guts they knew they were changing the world order. It is not inconsequential that the tune played as the British troops lay down their arms at Yorktown was *The World Turned Upside Down*. What they were moving from was a world where information was controlled by hierarchy. If folks at the top said the world was flat or species fixed on the deck of Noah's Ark, that was it, no argument, no doubts. The Revolution ended that.

Half a century later, Emerson wrote an epitaph to top-down thinking in his speech *The American Scholar.* In what has been called America's "declaration of intellectual independence," Emerson called for a new way of understanding, one not dependent on hierarchies or continental precedents, but one based on an individual's relationship with nature.

The conference on system dynamics was part of another intellectual revolution. Like Emerson's, this one was about changing an individual's relationship with the world, so we see it as systems of interrelated parts. Forrester devoted money, time—and most importantly, himself—to nurturing these seeds. Much as linguists believe children learn languages more quickly than adults because their minds are not as restricted by mental models, Forrester believed children are the future of system dynamics because their minds are more open to it. He spent much time supporting the Creative Learning Exchange, an organization dedicated to bringing system dynamics to K-12 schools, and the sponsor of the Concord area conference. It is as if Galileo had started street academies, Darwin taught in a public school, Einstein and Neils Bohr decided to put together a coalition of inner city schools.

Forrester prowled the halls of the conference, sat in on papers by high school teachers, lunched with school teams, and stood on the patio during happy hour, encouraging the efforts of K-12 people trying to bring the future to institutions that still are largely stuck somewhere between Horace Mann and the lecture method. For someone known to skewer a doctoral student with a few well-directed rapier slashes of logic, Forrester was extraordinarily open and patient at these affairs. He would sit through a presentation of a simple—and badly-flawed—model with rapt attention, and sometimes during, and sometimes after, would offer helpful comments intended to stimulate new and better ideas. In a sense he moved from tinkering with machines to tinkering with minds. Like a wrangler with a wild, unbroken colt, he would probe first with questions to understand more about the mind he was dealing with.

The world Forrester and others in system dynamics see is radically different from the one most of us have been trained to see. Jones Very once drew Emerson's famous "transparent eyeball" phrase from the essay, *Nature*, as a surrealistic eye perched on two stilt-like legs. Most of us still see the world as a box of parts that must be properly identified and sorted. Forrester, Sterman, George Richardson, Peter Senge, the late Barry Richmond, and others prominent in system dynamics see interconnections and feedbacks.

***Jay Forrester** continued on page 8*

Remembering Jay Forrester

continued from page 7

It is intriguing that a one-time tinkerer with machines should drive much of this new outlook. But it is not so hard to understand if you grasp the idea that Forrester was no ordinary tinkerer, anymore than Leonardo was an ordinary tinkerer. If you or I take something apart it is a pile of odd-shaped metal pieces that if we are half smart, we will figure out how to put together. Fits is the operative word—x connects to y—and we usually need a manual or someone's schematic in order to accomplish the task. We could not rebuild the device from scratch if we had to save ourselves and we surely would be unable to do it if we had a different set of parts or somehow had to make do with some approximation.

Forrester never saw things that way. He understood all those gears and pulleys and springs as systems. That is why he could take some substitute part and make the device work. Take the mainspring in an old-fashioned watch. Its tension provides the energy to drive the gears, but the energy has to be carefully calibrated with the size and number of the gears, how they fit together, the diameter of the watch face and even the weight of the hands. The winding knob on the outside was a major feedback device telling us the state of the tension in the spring.

Once you heard Forrester explain bathroom plumbing, home heating and other common mechanical devices this way you became caught up in the spell. Which is, of course, what Forrester wanted you to do. If you listened carefully enough you recognize in these explanations the precise mathematical beauty of a Bach cantata or Leonardo's drawings. You were inspired by the wonder and creative possibility of the human mind. To have heard Forrester speak was to come away an optimist about our future because you know somewhere out there is another youngster trying to swallow the world, to use Emerson's language. In these times of pessimism and anti-intellectualism, that may be Forrester's greatest contribution, just as it was Leonardo's. Forrester left you with a sense of how the human mind may think a century from now.

Ralph Brauer has sought to facilitate change to improve people's lives. He has served as a consultant on planning, research, data and cultural analysis for corporations, government agencies and professional organizations as well as writing for the New York Times Magazine, the Nation, and other publications.

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Your financial support of our effort here at *The Creative Learning Exchange* is always appreciated. You may donate any amount you wish; perhaps $50.00 is a reasonable amount for a year. All contributions are tax-deductible.

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

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