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Changing School Culture: Creating Student-Centered Classrooms

Tracy Benson

Tracy's chapter uses classroom and school stories to describe applications of operational thinking, one of Barry Richmond's eight systems thinking skills. These stories help illustrate how children and adults use operational thinking to organize concepts and communicate and improve mental models. The stories highlight the influence of systems thinking tools, especially stock-flow mapping and modeling, and reinforce the benefits the tools bring to students and teachers.

1990 was a pivotal year in my systems thinking approach to education. I was hired to join the Orange Grove Middle School in Tucson, Arizona, as their new assistant principal. For the previous three years, I had worked with Principal Mary Scheetz in a neighboring school district. During that time, we often talked about our vision for what middle level education could and should be: the creation of an environment where people with similar visions and passions could work together and do amazing work with young adolescents. Orange Grove Middle School became a place that attracted individuals who challenged themselves as learners, striving to create a school that functioned as a system and that honored the importance and quality of the relationships between all parts of the school. Although at the time we did not have access to current systems thinking terminology, we possessed an innate sense that school systems could be structured, and mental models influenced, so that joy in the workplace and exciting learning environments would be accessible to all members. We believed we could help create a school that could enthusiastically prepare children for the complexity of their adult futures as well as to achieve success by current conventional measures.

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Tracy Benson earned a B.S. degree in multi-field studies, and then moved to Tucson, Arizona, in 1978 to begin graduate work in exercise physiology and sports science at the University of Arizona.

She taught for nine years, at both the elementary and middle-school levels, as well as being an instructional coach. In order to broaden her ability to make a difference for children, she earned an M.A. in educational leadership from Northern Arizona University and spent seven years at Orange Grove Middle School as an assistant principal and principal.

It was during this time that her journey into systems thinking began as she met and worked with several influential systems thinking teachers and mentors.

None of this time for learning or envisioning systems thinking in schools would have been possible without the long-term support and encouragement of Jim and Faith Waters, who have helped bring the work of systems thinking to schools across the U.S. and throughout the world.

Tracy went on to earn her Ed.D. in educational leadership from the University of Arizona and has been a coordinator of The Waters Foundation, Systems Thinking in Schools project.

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Dr. Gordon Brown, an Orange Grove neighbor and professor emeritus from MIT, was our "citizen champion," reminding us that once we had learned about systems thinking and system dynamics, our lives would never be the same. In addition to bringing system dynamics to our school, Gordon connected us with Mr. and Mrs. James Waters, whose guidance and support became an enduring part of the work at Orange Grove, and who, through the Waters Foundation, have helped spread systems thinking and system dynamics in schools well beyond our small middle school. Through the organic energy and synchronicity that flowed through Orange Grove at the time, Gordon Brown also arranged for us to meet Barry Richmond, one of our first systems thinking teachers.

After being introduced to systems thinking, I, along with fellow educators, came to understand that young people could build systems thinking models to help operationalize their understanding of the dynamics of the systems they were studying in a wide variety of subjects including science, social studies, and reading. If models influence the thinking and attitudes of those who see them, as in the case of either computer models or role models, then the level of accuracy models project can weigh heavily on the modeler's mind. As educators learning systems thinking, we recognize the level of skill and practice needed to create realistic models. Luckily for us, George Box's statement, "All models are wrong, but some may be useful," (often reiterated by Dr. Jay Forrester and other system dynamics mentors) reminds us that the models we create will never be perfect or completely accurate (Box 1979); nonetheless, we have learned from experience that the operational thinking used when building models at all levels can be significantly beneficial to teachers and students. Operational thinking requires you to focus on understanding how underlying processes are put together.

tracing connections

As a mentor to educators, Barry Richmond helped us see a whole new perspective of what creating a model of a system could be. He guided and expanded our understanding of the concept of model. He asked and encouraged questions: "How does a system of interest really work?" "What underlying structures create the behaviors we see?" "How can we help others 'see systems'?"

The result of such questions was that, instead of creating a simple model showing individual parts of an ecosystem, we might ask ourselves and our students to create a model showing how elements of an ecosystem, such as populations of different species and components of a habitat, interact to create the dynamic behaviors we observe in the real system. Barry invited us to shift our focus from listing factors that are part of a system to deepening understanding of how systems *really* work. Could students, even those in the younger grades, ask such questions? Could they really create such models?

Experimentation, risk-taking, and learning new skills on the job are not easy for most, including educators. Teachers are expected to know their curricula, to manage classrooms effectively and efficiently, and to provide students with experiences that encompass rigor and relevance. Experimentation and applying "new ways of teaching" that hadn't been used widely in K-12 classrooms was uncharted territory and became quite unnerving for many of us. Luckily, we had Barry and other mentors to guide and expand our understanding of the concepts of systems thinking and dynamic modeling.

By understanding that imperfect models can still be useful, teachers and students are free to use a process of rigorous experimentation and dynamic model construction to gain insight about the systems the study.

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Teachers tend to struggle with a number of topics as they learn about systems thinking and system dynamics. Is there a proper developmental sequence when using systems thinking strategies with students? Is it okay to try to incorporate some of the tools if I am still learning about them myself? I remember in-depth conversations about the use of causal loops versus stock-flow maps when operationalizing a problem. We would ask, "Which should come first, loops or stock-flows?" "Is there a proper sequence for introducing specific tools?" Discussions about the distinction between systems thinking and system dynamics were guided by Barry's insight that "the differences are more in orientation and emphasis than in essence." He further described systems thinking as "system dynamics with an aura," which is further described in his paper entitled

"System Dynamics—Systems Thinking, Let's Just Get On with It." It was Barry who encouraged us not to fixate on the details of perfect system dynamics practice, but rather on what was really important for students to learn and investigate. He reminded us that "individuals who generate insights for themselves learn much more than those who are fed them." He would encourage us to refine our own skills and look for new ways to apply those skills and technologies of systems thinking to classroom instruction. A recollection of his advice went something like this: "Don't worry about trying to be perfect system dynamics practitioners; focus instead on how you can help students 'see systems' as they investigate complex problems."

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Barry's message focused on what is best for children. To illustrate this message, I share the following stories of students and teachers who have used operational thinking to address particular problems. The stories highlight lessons learned and show the benefits of operational systems thinking. As a teacher and mentor, Barry was truly one of the best; he supported us as we learned directly from our experiences working with young people.

Bryan's Story: Crocodiles and New Insights

Fourth grader Bryan was an eager learner, interested in many things but was often reluctant to conform to day-to-day classroom expectations. As a part of a unit on endangered species, students were asked to choose an animal, then conduct research and prepare a written report that included a stock-flow map. With the knowledge he was free to choose his own animal, Bryan enthusiastically chose to study crocodiles and immersed himself in crocodile research. His stock-flow map included several key variables that had influenced the steady population decline of his chosen species, the crocodile; size of habitat, effects of hunting, and consumer demand for crocodile skins were among the variables.

One year after he completed his project, Bryan was asked to share his work with a group of adults interested in using stock-flow mapping with children. As he was sharing his fourth grade project presentation-style in front of a large audience of adults, he stopped in the middle of a sentence because he realized that as an older and wiser fifth grader, he did not quite agree with particular parts of his fourth-grade model. At that unplanned moment of his talk, he openly shared that his thinking had obviously changed since fourth grade because he noticed he hadn't put in a connector between food and the population stock, and that

he needed to both "add and delete some arrows and change a few other parts." The adults in attendance learned that Bryan's stock-flow map did more than help him develop an operational model of his system. The map was a representation of his understanding at a particular time of his cognitive development (fourth grade). As he discovered during his "aha" moment, the sophistication and accuracy of the map could truly improve over time as his own level of thinking and understanding matured.

Stock-flow maps help children represent their current thinking as a visual display. Because the maps help children communicate complex thoughts in a very visual manner, children are able to revisit their thinking and recognize their own growth as their theories and thought processes develop over time, whether that span of time is a day, a week, or even years!

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Eight Grade Math Class: Special Needs to Confident Achievers

Ms. Dunham was an eighth-grade math teacher of children identified as having special needs. These young people had poor images of themselves as students and often expressed self-deprecating comments about their own capabilities, especially in math. Like all students in the school, despite their learning difficulties, they were expected to participate in the same standardized testing as other students. The eighth-grade tests included abstract algebraic concepts that appeared to be far beyond the capabilities of these special needs students.

Since Ms. Dunham was open to different instructional strategies and willing to use them if they could benefit her students, she decided to apply some of the new systems thinking strategies she had recently learned. She taught her students to build simple linear stock-flow models of a shoe factory, to use a hands-on approach to simulate factory manufacturing and consumer spending, to keep track of data in charts and graphs, and then to proceed to build simple STELLA computer models of their economic systems. The computer model simulations helped the students learn the concept of slope and the algorithm y=mx+b; the difference between linear and nonlinear functions; and most importantly, enhanced their view of their own capabilities. One student was overheard saying, "Building these computer models—this is the first time I feel really smart in school."

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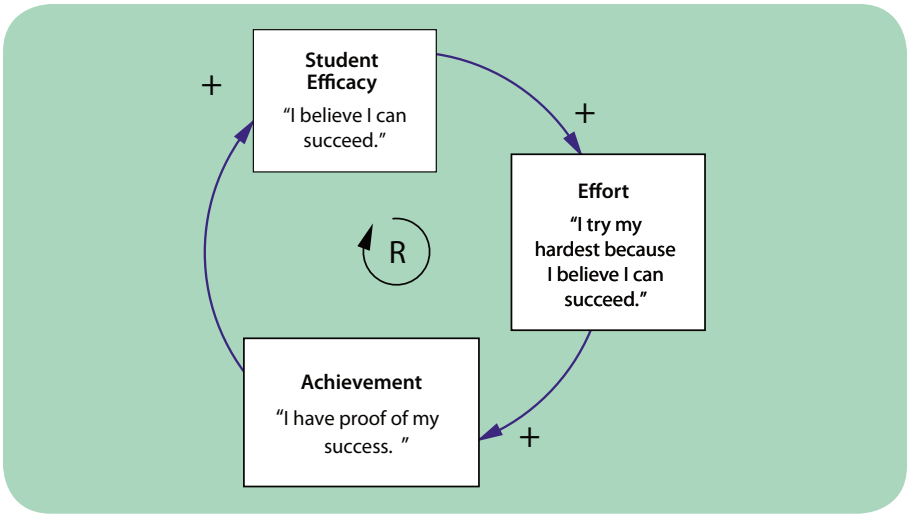

Figure 4-1. Reinforcing loop of student effort and efficacy

Efficacy is a person's ability to produce a desired result. Students who are efficacious believe they have the ability to learn new skills or achieve prescribed standards. By building on a renewed sense of efficacy, this group of once perceived-to-be-struggling math students were asked to teach peers enrolled in the advanced eighth-grade algebra class how to build the same computer models and how the models connected to the algebra concepts they, too, were learning in class. Needless to say, as perception became reality, Ms Dunham's students gained far more from the experience than just enhanced understanding of linear functions and improved performance on written assessments. They discovered a new view of themselves as learners and they projected that positive self-image to their studies and to their interactions with peers.

From this example and other similar documented anecdotes, a theory of efficacy and effort emerges.

This snowballing, reinforcing story, as shown in Figure 4-1, reveals the power of systems tools and strategies. As students learn new ways of representing complex or abstract concepts, they develop a greater sense of self-efficacy, which then motivates them to try harder and persist. Every teacher knows that when students put forth strong effort, they tend to achieve success that, in turn, feeds their sense of efficacy. We have learned that students of all

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backgrounds and capabilities can use systems thinking strategies to help them learn and that capability bolsters their belief in themselves as learners.

Introduction of Systems Strategies in a School Setting: The Bathtub Analogy

As a middle school principal, Mary Quinnan was determined to use systems thinking strategies with her staff as a means for enhancing the overall quality of her school. She had participated in a series of systems training sessions, attended a system dynamics conference, and believed strongly that her staff and students would benefit from a systems thinking approach.

During professional development time with her teachers, Quinnan used causal loop archetypes, behavior-over-time graphs, the ladder of inference, and stock-flow maps (available at http://www.watersfoundation.org) to facilitate in-depth conversations and problem-solving about real school issues. When Quinnan introduced stock-flow maps to her staff, she hung a very large drawing of a bathtub on a white board and then proceeded to explain the dynamics of changing water levels and how the related actions of the faucet and the drain influenced the level changes. Since the familiarity of the bathtub seemed obvious to the teachers, she then posed a series of questions: "If we use the water as a metaphor for student engagement during instruction, what is currently happening to the changing level of the engagement water in your classrooms? What would we need to do to minimize the draining out as when students shut down and disengage in class? What would we need to do to turn up the faucet so that students were motivated and excited to actively participate in class?" These questions led to lively discussions, eliciting numerous ideas to both shut down the drain and turn up the faucet so that there would be increased classroom involvement and participation. Groups of teachers used stock-flow drawings to map out their ideas and to predict the results of new strategies. As with the students, the stock-flow maps helped the teachers visually represent the existing state of their classrooms along with what it would take to increase the engagement accumulation over time.

As Quinnan taught and demonstrated systems strategies when working with her staff, she also encouraged them to use the same strategies in their classrooms as an instructional approach.

A wide variety of efforts contributed to the positive student achievement results at Quinnan's school. Systems strategies played a significant part as a means for making staff collaboration and problem-solving visual and cohesive. As Quinnan taught and demonstrated systems strategies when working with her staff, she also encouraged them to use the same strategies in their classrooms as an instructional

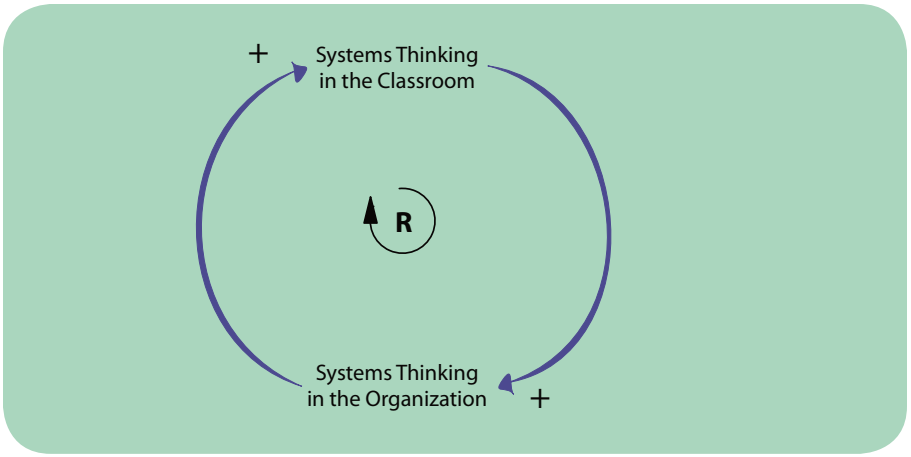

Figure 4-2. Reinforcing nature of the use of systems thinking in the classroom and organization

approach. A feedback loop depicts the reinforcing relationship between the incorporation of systems thinking applied to organizational issues and systems thinking woven into classroom instruction. The reinforcing nature of this dynamic truly contributed to a positive learning environment and enhanced student achievement, as Figure 4-2 indicates.

Systems Thinking in Early School Years

Some adventuresome teachers at Borton Primary Magnet School in Tucson, Arizona thought their very young students (kindergarten, first, and second grades) would benefit from knowing how to build stock-flow models. The teachers saw the value as students identified the stocks, or the main things that change in a system, and the flows that influence the changes. In these primary classrooms, examples of stocks included the amount of soup in a stock pot, amount of water in a bath tub, number of passengers riding in a fictional trolley car, the amount of courage a character develops as described in fiction and nonfiction literature, and the number of people visiting the zoo while on a field trip. Students discussed the nature of the change of the stocks and drew the flows as simple increasing and decreasing rates that either made the level of the stock go up or go down. What was surprising to teachers was the ease with which the students embraced the visual nature of the stock-flow tool.

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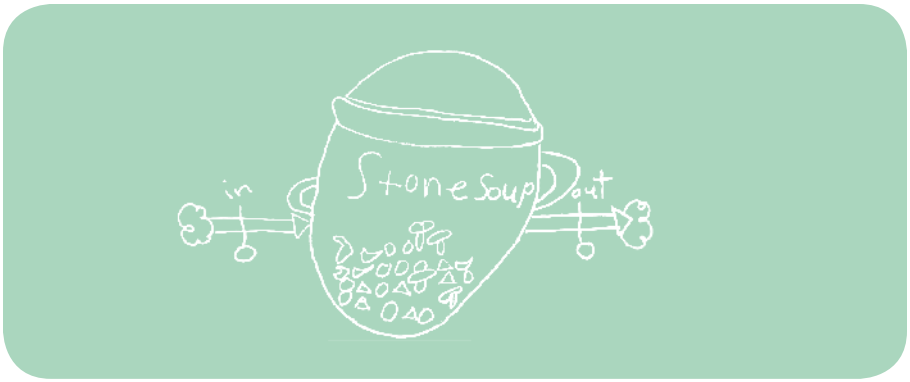

Figure 4-3. Stock-flow map of stone soup: Drawn by Lizbeth Loreto, kindergartener

Stock-flow maps helped children represent their understanding of stories, concepts, and scenarios, not just as static pictures, but as dynamic entities that change over time. Several anecdotes demonstrate how easy it is to underestimate the capabilities of young children. In one classroom a teacher used the book *Stone Soup* to introduce accumulations and rates as stock-flow concepts. Soup in a stockpot was the accumulation (stock) of interest. Parents were invited to come to class and eat the soup from the stockpot. While discussing the outflow of soup in terms of cups of soup served to the parents, one child said, "What about that steam that is coming off the top—isn't that part of the outflow, too? It is not just the soup leaving because we are eating it."

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Another example involves a second-grade teacher who was curious as to whether her students were able to build simple computer models using STELLA software. She chose seven of her more verbal, confident students and in less than an hour taught them the basic icons and manipulations of the software. To more effectively introduce computer modeling to the whole class, her plan was to use her seven student-leaders as peer-to-peer guides and pair them with others in the class. After instructing the student guides for 45 minutes, she paired them up with their classmates and asked them to direct their attention to a screen that projected a blank STELLA modeling page. She proceeded to provide basic introductory instruction that included placing a stock on a page and labeling it, and expecting the pairs of students to follow along with her. It took no more than three minutes of instruction before she realized that all of her students were way ahead of her instruction. Their attention was not on the teacher or the screen because they were focused on one another, their own computer, and the task

of building a simple model. The student guides were busy teaching and guiding the novices while needing no assistance from the teacher. Seeing this level of independence, the teacher turned the projector off and proceeded to walk around, listen to the partner conversations, and watch with amazement as the students taught and built models with one another. The teacher exclaimed, "It took me practice time and courage to feel comfortable enough to introduce this in my classroom! I invested only 45 minutes of instruction with only seven of my kids, and they don't even need me any more! Why do they catch on so much quicker than adults like me?"

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The teachers of Borton Primary Magnet School continue to be active systems thinking teachers, and their innovative work has been recognized internationally by companies like Microsoft. Students are expected to operationalize their thinking using the visual tools of system dynamics (e.g., behavior-over-time graphs, stock-flow maps, causal loop diagrams, and simple models). Those tools have become part of the learning repertoire for primary school children at Borton Primary Magnet School as they address relevant problems with skill and confidence.

In a student-centered systems thinking classroom, teachers and children, such as those at Borton, are the facilitators of thinking and learning. Children are immersed in practice fields rich in relevant problem-solving, interdisciplinary connections, thought-provoking dialogue, and opportunities for in-depth analysis and synthesis. The Waters Foundation's "Systems Thinking in Schools Project" is focused on supporting teachers in their ability to create such desirable learning environments for children. A systems thinking learning environment is motivating and engaging for even the most reluctant learner, as we saw in the eighth-grade math class. The teachers in Mary Quinnan's school and students like Bryan make it apparent that the visual nature of the systems thinking tools enables individuals to organize, express, and make operational their thinking. Philosopher Rene Descartes once said, "We do not describe the world we see; we see the world we can describe." As systems thinkers learn how to "see systems" by way of operational thinking, the complexity of the world becomes more visible and manageable.

The Goal: Building a Systems Citizenry

The ability to see systems and manage complexity is integral to the development of twenty-first century citizens. In a keynote address delivered to educators in July of 2002, Barry Richmond referred to the importance of developing "systems citizens." Systems citizens view themselves as members of a global community. They strive to understand the complexities of today's worldly systems and have the ability to tackle problems with an informed capacity to make a positive difference. Schools across the United States and throughout the world are actively pursuing the advantages of integrating systems thinking and system dynamics in classrooms and schools. The benefits of such approaches are both immediate to student learning and long lasting, as a systems citizenry is developed and nurtured.

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From 1990 through the present, educators from Arizona, California, Colorado, Georgia, Iowa, Massachusetts, Michigan, Missouri, New Mexico, Oregon, Texas, Vermont, China, India, The Netherlands, Singapore, and elsewhere have benefited from Waters Foundation Systems Thinking in Schools training, workshops, and presentations. We are often asked to estimate the number of educators who are integrating systems thinking into their classrooms and schools and the number of children who benefit from this methodology. Responding to this question is challenging because the contagious nature of the work makes it hard to quantify, yet at this point we confidently respond with a number hovering in the thousands. We know that after introductory training, some educators choose to emphasize the language and habits of systems thinking, while others, in addition to the habits, focus on the visual tools and computer modeling that help students operationalize their thinking. One beauty of systems thinking is the ease with which educators can connect and apply any aspect of systems thinking, from the habits to computer modeling, within prescribed curricula and established standards.

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Knowing that successful learning environments are characterized by a wide range of teaching strategies that motivate, challenge, and engage students of all strengths and capabilities, educators who are invested in systems thinking approaches have the capacity and tools to create such classrooms, at the elementary, middle, and high school levels. System thinking has been integrated

into schools serving urban, rural, and suburban communities and in public, charter, and private school settings.

Barry's message lives on as a new emphasis on citizenry and critical thinking headline educational agendas. In a 2008 report by the Forum for Education and Democracy, "Democracy at Risk: The Need for a New Federal Policy in Education," leading researchers cite the importance of twenty-first century skills that focus on critical thinking. The researchers assert, "We will need to foster major changes in curriculum and assessment to support the critical thinking and problem-solving required for success in the complex society we live in today." Barry Richmond has been an inspiring mentor for K-12 educators, and his legacy continues through the work of systems educators who strive to develop a systems citizenry to lead us through the complexity of the twenty-first century.

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