Developing Capacity for Systems Thinking in Schools[1]

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Abstract

The Systems Thinking in Schools programs, supported by the Waters Foundation, serve to build systems thinking and modeling capacity in teachers and students nationwide. The Creative Learning Exchange also serves to increase system dynamics and systems thinking capacity in school communities through dissemination of curricular materials and a biannual conference. Because the field of systems thinking in education is so new and substantive research findings are limited in scope, there is a need to expand programs and curricular applications to gather evidence of improved learning outcomes. Before more research can be done towards measuring learning outcomes, there is a need to understand the barriers for both new Systems Thinking in Schools movements being initiated, and for established movements maintaining support and capacity. To best address this discrepancy in understanding, the author finds it most productive to create visualizations of the situation with the help of stakeholders and literature. Through a system dynamics framework, the author will construct a model to empower schools looking to include systems thinking in their curriculum and programs.

Keywords: systems thinking, system dynamics, Waters Foundation, Creative Learning Exchange, ecosystems of innovation, disruptive innovation, communities of expertise, communities of practice

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1. Author Background

Through my background studying applications of Educational Psychology, researching system dynamics modeling, and working with youth in St. Louis schools, I found myself conducting interviews, reading literature about the potential for systems thinking to transform the classroom experience, and subsequently developing models to visualize the situation. My research in this area has connected me to incredible teachers and educators, experts in the fields of education reform and creativity, and civic leaders across St. Louis and the country. At this point, I feel called to do this work, understanding the barriers facing teachers and school communities looking to teach systems thinking and modeling to their students such that they can be more effective problem solvers. I believe in the potential for a new generation of "systems citizens", and I plan to do everything within my spheres of influence to understand what prohibits such potential from being realized.

My goal is to summarize conversations with leaders in the field such that a shared perception of the situation can be established. The findings I contribute are not my own, rather they capture a collective theory of a community. This paper captures stories, beliefs, and proposed dynamics such that everyone involved can share the understanding of the current situation surrounding systems thinking movements in schools.

2. Orientation to the Problem

There are gaps between what skills students need to be successful in the work force and what schools are providing. In this rapidly evolving economy, there is a significant need for individuals with creative thinking abilities, excellent problem solving skills, and experience working with others to develop solutions to problems. More often than not, students graduate without any of these, much less, sufficient backgrounds in math and writing. The more years that students spend misunderstanding the concepts of accumulation, dynamic equilibrium, and other dynamic processes, the more of a deficit is formed in their understanding of complex systems. A study by Sterman and Sweeney evaluated MIT Sloan School of Management students' abilities to understand accumulation in stocks, and results indicated misconceptions of basic principles of integration when applied to dynamic systems (Sweeney and Sterman, 2000). The authors conclude, "good mathematics training alone is not sufficient to develop a practical, common-sense understanding of the most basic building blocks of complex systems" (Sweeney and Sterman, 2000). Independent of age or background in mathematics, students evolve to develop heuristics for decision-making that are context-specific, therefore they lack heuristics to transfer to increasingly complex and difficult problems. Even highly educated individuals, such as those at the Sloan School of Management, have significant trouble understanding accumulation and the concepts behind stock-and-flow diagrams.

Students today are shown to have significant difficulty understanding complex systems, creating substantive arguments to support their opinions and perceptions, and struggle to perceive the systemic implications of their actions and decisions (Zuckerman & Resnick, 2005). There is a need to redesign the classroom experience for students to better prepare them as the next generation of creators and problem solvers. Based on the proposed learning outcomes of systems thinking-supplemented curriculum, described in depth below, the creation of more systems thinking-centric programs and classes can help students achieve the ideal skill set for today's workforce.

Systems thinking is a set of techniques that students can use to comprehend and express the complex systems around them. These complex systems can range from understanding the present and future accumulation of CO_2 in the atmosphere to planning how many cookies to bake based on the fluctuating rate of sales in a bake sale. In both of these situations, the problems are dynamic in the sense that the rates of inflow and outflow are constantly changing, there are delays in rate changes, and there are parts of the problem that are connected distantly (i.e. ocean absorption of CO_2, word of mouth about cookie quality) that affect the immediate problem after some time passes. Systems thinking empowers students to create visualizations, drawings of these problems such that they can see their agency to change the system in a way they could not before. In the words of L. Booth Sweeney, "when we are unaware of dynamic structures, we are more likely to react to behaviors produced by them, rather than to understand and potentially take actions to change the structures" (Sweeney, 2005). Training in drawing visualizations of problems helps students to transition from reactive problem solving to developing proactive and better-substantiated approaches to creating action plans.

The skills that students learn from systems thinking-supplemented curriculum are crucial to their development as global citizens. According to Dr. Barry Richmond, "systems citizens are *being* the changes they wish to create in the world, but… they also know how to best pursue the systemic orchestrations required to bring those changes about" (Benson, 2007). They better perceive their oneness with others and the implications of their decisions and actions on others. These abilities for students to perceive systems around them and their place in systems are not improved and developed without effort. As Peter Senge notes, "children do not have to be taught to interpret their reality. They are doing it continuously. But their ability to steadily expand this instinctive sense making into more and more complex subjects must be developed over time. Failure to do so contributes to the growing gap between the complexities of our world and the understanding of our citizens" (Benson, 2007).

The process of developing system dynamics models and concurrently reconstructing one's own mental models is a very interactive, experiential, and kinesthetic learning process. "Experiential learning theory defines learning as 'the process whereby knowledge is created through the transformation of experience. Knowledge results from the combination of grasping and transforming experience'" (Benson, 2007). This has been shown to be true with Ritenour students in the Systems Thinking In Schools movement in St. Louis, Missouri. For the past several years, students in Ritenour School District have been taught systems thinking in the classroom and in extracurricular programs. By working through a series of theoretical and real conflicts within their social and academic lives, Ritenour students have transformed their perceptions of the reality surrounding them. Students have learned better means of conflict resolution, developed broader perceptions of the problems at hand, and learned to better articulate and support arguments they present.

It has been shown in several cases that students who have access to model structure learn more than students receiving only narrative instruction (Wheat, Weathers, & Goldstein, 2004). Visual framework that arises from systems modeling makes knowledge more relevant and meaningful. Jerome Bruner suggests, "unless detail is placed into a structured pattern, it is rapidly forgotten" (Wheat et al., 2004). "Bruner's structured pattern is Jay W. Forrester's system dynamics '… a framework into which facts can be placed [so that] learning becomes more relevant and meaningful'" (Wheat et al., 2004).

Regardless of the postulated benefits for students, there is a need for more evidence of the efficacy of systems thinking-supplemented curriculum for improving learning outcomes.

According to Sterman and Sweeney, "the challenge facing educators is not only to develop new ways to teach these skills, but also to measure the impact of such courses on students' ability to think dynamically and systemically" (Sweeney and Sterman, 2000). When educators are able to measure the impact of their work with systems thinking, they can then identify when certain students are struggling with material, and can foster a more meaningful learning experience for each student.

Systems thinking movements are being implemented in school communities nationwide, and while the technologies and pedagogies surrounding these programs are not substantiated by much evidence, the preliminary learning outcomes for students involved show the value these programs provide. The ecosystems of innovation surrounding Ritenour School District's Systems Thinking in Schools movement and Maplewood-Richmond Heights' work with systems thinking in science and nature are excellent examples that highlight the symbiotic relationship between experts in the field and community partners that foster successful programs to teach systems thinking in schools. Through relationships with the Waters Foundation, Washington University in St. Louis, and strong district-level administrative buy-in to systems thinking, these schools have built strong movements to improve the classroom experience for their students.

In regards to implementing new systems thinking-supplemented curriculum, there is a significant need for actors in the community and school that have backgrounds learning or teaching systems thinking to others. Many barriers to entry exist for schools starting systems thinking programs. Barriers include institutional pushback, lack of social capital, and a deficiency of instructors with sufficient training in systems thinking instruction. One of the greatest barriers to forming new programs in schools is a disparity of expertise in systems modeling, systems thinking, and other approaches to solving dynamic and complex problems. Without administrator, teacher, and student buy-in to the program with its proposed learning outcomes, there is a much steeper hill to climb for newly forming systems thinking programs. St. Louis is unique because there are many community and university actors with backgrounds in systems thinking along with administrators with significant investment in Systems Thinking in Schools' programs succeeding in Ritenour School District and Maplewood-Richmond Heights. How can other communities position themselves to introduce the systems thinking movement in their schools and communities?

It is possible that the successes of the systems thinking movements in St. Louis are not only the result of ecosystems of innovation, but they are also due to the disruptiveness of systems thinking in the education field. The purpose of disruptive innovations is to identify gaps within the market and develop solutions that are more accessible, less costly, and address the needs of otherwise underserved populations. "Disruption is a positive force. It is the process by which an innovation transforms a market whose services or products are complicated and expensive into one where simplicity, convenience, accessibility, and affordability characterize the industry" (Lagace, 2008). Systems thinking is disruptive in several ways within the pilot programs' respective communities. Systems thinking movements disrupt the typical structures surrounding interactions within school communities bringing together administrators, teachers, and community members to collectively address the common goal of improving learning outcomes for students. They also increase modeling and systems thinking capacity for teachers and students, populations that would otherwise operate without these capacities. More research must be conducted to fully understand the catalytic capabilities of these innovative pedagogies and practices.

In conclusion, there is a need to better equip students as productive and creative problem solvers by the time they graduate high school. It is apparent that systems thinking can help students understand increasingly complex problems, but there is an insufficient body of evidence to prove this. In order to scale up these programs and acquire more evidence of learning outcomes, we must identify best practices for communities starting systems thinking movements. There is a need to understand what environmental factors and actors in the community lend themselves to movements thriving. Relying on a series of interviews and comparative evaluations of literature and similar programs, we can identify trends of scale-up and diminishing of capacity in communities looking to develop systems thinking and modeling skills for administrators, teachers, and students.

3. Reference Mode: Sustainable Growth vs. Overshoot and Collapse

After consulting with experts at the Waters Foundation and Creative Learning Exchange, I developed a reference mode around issues of scale up and maintaining capacity for Systems Thinking In Schools. Based on past trends and the potentially more conducive environment for these movements in coming years, the desired behavior mimics that of an infection model with S-shaped growth. The long tail in the beginning highlights the prior trends seen with introducing new classroom practices. It has taken much longer than expected to scale up the number of teachers using systems thinking in the classroom.

There are several feared behaviors within this reference mode. “Feared 1” shows overshoot and collapse behavior, indicating an initial rapid increase in number of teachers using systems thinking in the classroom with subsequent rapid decrease in teachers due to a lack of capacity and support. After a series of interviews, I have identified trends of systems thinking gaining initial buy-in and support on the part of teachers and administrators with a gradual diminishing of support after several years have passed. Rather than the number of teachers using systems thinking returning to the initial value, the overshoot and collapse behavior ends at a higher level indicating that some teachers are able to maintain their use of systems thinking, but not as many as hoped. It is hoped that this behavior can be ameliorated with the creation of stronger support systems and better-substantiated evidence of the learning outcomes of systems thinking-supplemented curricula over time.

With “Feared 2”, the percentage of teachers using systems thinking in the classrooms increases towards the desired behavior, but is not maintained over time and gradually diminishes. This serves to indicate the lack of sustainability of some movements due to teachers leaving the district over time, not enough novice teachers being trained, or elimination of access to resources by administration due to diminished support for the use of systems thinking.

The behavior shown in “Feared 3” indicates little or no change in the percentage of teachers using systems thinking in the classroom. This is the most feared outcome, the result of failed interventions and policy changes in participating schools.

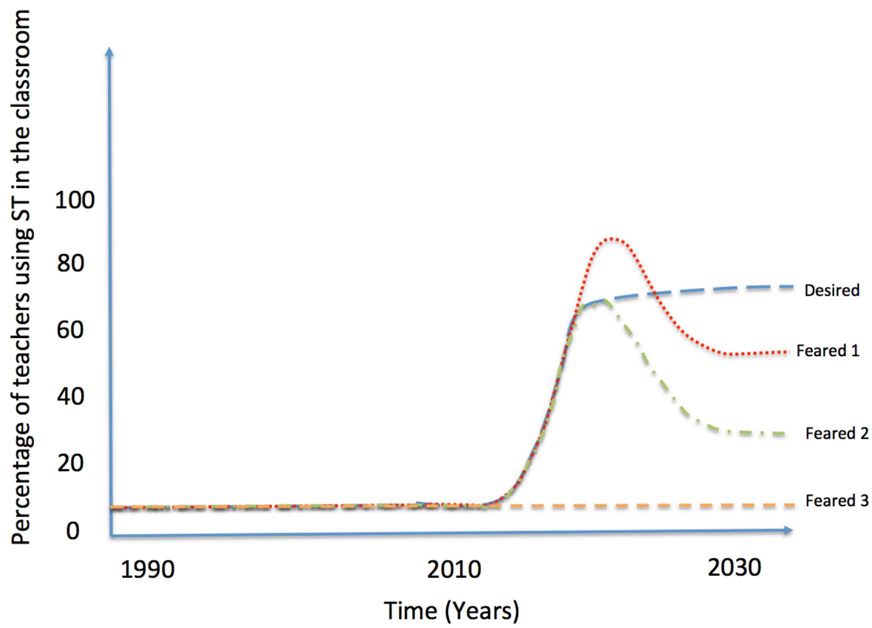


Figure 1: Reference Mode

4. Process and Model Conceptualization

Over the course of conducting interviews and identifying relevant variables and structure, I developed a series of prototype models. These models were the results of conversations with mentors and stakeholders along with aggregation of previously conducted literature reviews. All of the models represented the different possible contexts that have allowed programs to thrive and fail to thrive through several potential frameworks. These frameworks included: Development of Expertise, Disruptive Innovation in the Classroom, and Place-Based Innovation.

The first framework I eliminated from further iteration, "Development of Expertise", addressed the training of teachers and the aggregated skills that accumulated after training. It showed the gain of skills through initial and subsequent training along with the loss of skills when teachers left the Systems Thinking In Schools (STIS) movement or retired. I factored in the importance of a large "Expert/Novice Ratio" as it pertained to training of new teachers. According to several stakeholders I interviewed, with a greater number of Expert Teachers in a school environment, there was greater support for the use of systems thinking in the classroom along with better-substantiated curricular applications for Novice Teachers to use and avoid past mistakes. With this framework, there had to be sufficient training of teachers with capacity to start their own classroom practices around the use of systems thinking and system dynamics modeling. After consulting further with stakeholders I interviewed over the past several months, we concluded this model was too simplified to capture the complexities of administrative buy-in and the need for support systems around training of new teachers in systems thinking tools.

The second framework I developed and later abandoned, "Disruptive Innovations in the Classroom", portrayed the use of Systems Thinking in the classroom as a disruptive innovation. The sustaining innovations in the model were those that maintained the status quo and appealed to standards that classrooms had to reach yearly. Systems Thinking is disruptive in the sense that it builds systems thinking and modeling capacity in the population of students taking the courses, along with increasing the teachers' capacity to apply systems thinking to material being taught. These populations develop significant modeling expertise otherwise relegated to researchers and consultants in the field. With a dissemination of these skills, a broader population of individuals is able to apply principles of systems design and modeling techniques towards problems they face in everyday life. This model served as a micro-level view of individual teachers making the decision to use sustaining or disruptive pedagogical innovations in the context of a classroom.

Sustaining innovations were those that maintained the standards set in previous years, whereas disruptive ones entailed the introduction of new pedagogies and practices to supplement past practices. These "disruptive classroom innovations" included the introduction of systems thinking-supplemented curriculum and modeling instruction for students. The more adopters of disruptive innovations (teachers using systems thinking in the classroom), the higher the prevalence of disruptive innovators became, therefore the Word of Mouth effect surrounding systems thinking pedagogies increased. When this Word of Mouth effect increased, it was expected for more teachers to make the transition from utilizing sustaining practices in the classroom to using more innovative and disruptive ones to supplement or replace old practices.

With improved classroom practices and experience, it was expected for the quality of systems thinking curricula to improve. Through improvements in quality of systems thinking curricula, I expected the innovative capability of systems thinking programs to improve. The strength of programs increased in the form of new applications of systems thinking in the classroom, increased teacher capacity through experience and training, and increased buy-in to programs resulting from evidence of improved learning outcomes for students. This increase in capability increased the effectiveness of the Word of Mouth effect on attracting new teachers towards transitioning to using systems thinking in the classroom. With serious consideration and further study of literature, I concluded that this model made very broad assumptions about the disruptiveness of systems thinking in schools. It relied heavily on existing frameworks for disruptive innovations in the business world, and as such, did not reflect the insights from interviews I collected. Therefore, I eliminated this model from consideration in further work.

The third framework I eliminated, "Place Based Innovation Surrounding Interventions", was an augmented version of a previous model that attempted to capture the relationship between universities and their proximal communities as it affected community-based interventions. After consulting further with mentors and stakeholders, it was not productive to only consider interactions between universities and surrounding communities, but between communities of expertise and practice. There were many other sources of expertise in communities outside of universities, with a more diverse and realistic series of connections to infrastructural, intellectual, and financial capital.

The goal of successful interventions in communities is threefold: to address a community-relevant problem, to come about through "embedded interactions" (collective problem-solving processes), and to engage relevant stakeholders in the formation of problem-solving teams. This version of the model took into account the connections between communities of expertise (i.e. universities, Waters Foundations experts, experts in systems thinking) and communities of practice (i.e. teachers, administrators). There was a Word of Mouth variable to take into account the effects of successful interventions towards developing capacity. It also included structures that modeled the need for identification of community relevant problems to be solved by collaborative problem-solving teams.

With an increasing number of successful interventions, there was a resulting Word of Mouth effect that came back to increase the variable named "Development of Capacity". As more and more interventions were successfully implemented and began building social capital within the respective communities, the word spread about the successes achieved by problem solving teams, and therefore increased the perceived effectiveness of these teams.

The more collaborative this identification of community-relevant, achievably resolved problems became, the more agency the actors within communities of expertise and practice had towards making the intervention successful. There was a gap between all possible community issues the problem solving teams could address, and those which were identified as "relevant and achievably resolved" by the community actors. For more interventions to be successful, it was necessary for the process of framing and identifying the problem to be collectively designed and implemented by experts and relevant stakeholders in the community. This could take place within a focus group context, in the form of a Group Model Building Workshop, or through an extensive qualitative interview process between experts and stakeholders.

To achieve successfully collaborative ("embedded") interactions between communities of expertise and communities of practice, there was a need for identification of relevant actors within both realms. If actors were chosen based on relevant skill sets and social capital, there was a higher likelihood for the intervention designed and subsequently implemented to be successful. More research needed to be done to substantiate the reasoning behind choosing particular parameters and building structure around this practice. While this model effectively captured the need for collective action towards addressing community needs, it was so vast and complex that it did not provide much insight to the issues facing Systems Thinking in Schools movements. I plan to expand upon this structure in future years as a means to understand university-community interactions and initiatives, but I have eliminated it for now to focus on a more relevant structure.

After further iterations and redevelopment of these frameworks, I concluded that the model "Development of Capacity" best encapsulated the insights of interviews and literature reviews. As a result, I have chosen this model to simulate and analyze to better anticipate the implications of different interventions and policy changes**.**

5. Model Description

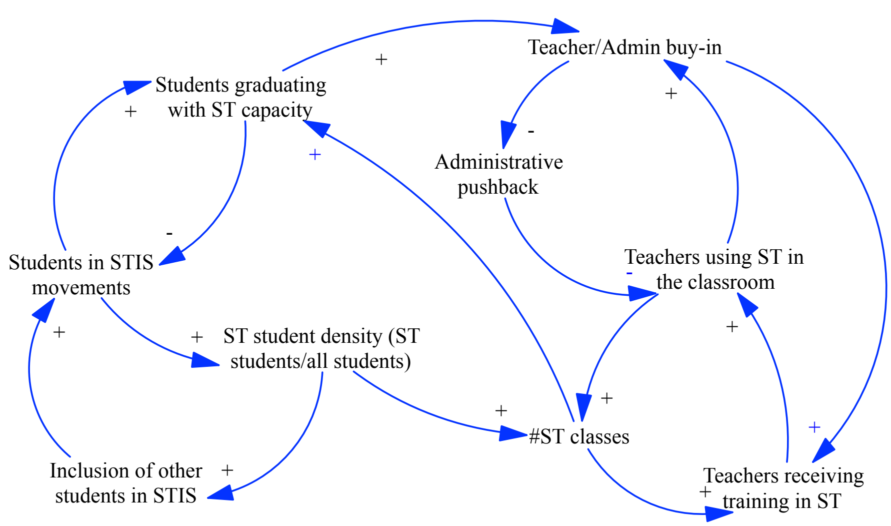


Figure 2: Developing Capacity

The causal loop diagram above, "Developing Capacity", was built from several conversations with communities of expertise and communities of practice at Washington University, Ritenour School District in St. Louis, Maplewood-Richmond Heights Middle School, and members of the Creative Learning Exchange. The structure highlights the need for more trained teachers, sufficient buy-in from schools, and engagement of a large number of students for programs to be initially successful and maintain capacity.

Because there is not much data available for the number of movements in existence or teachers using systems thinking in the classroom, I have relied heavily on an aggregation of stories to inform the dynamics of my model. I have found these stories through interviews with teachers, administrators, and experts that have worked to increase the number of students encountering systems thinking in the classroom.

St. Louis, Missouri is a place to watch in terms of applications of systems thinking in the classroom. There are several district-wide systems thinking movements in place that have supported their students from the elementary to high school level in using systems thinking and modeling tools for their academic and social lives. While some schools have more thriving movements than others, there is a culture of support and collaboration around applications of systems thinking in the classroom for teachers and administrators looking to improve the classroom experience for students. The support of the Waters Foundation in St. Louis along with its annual Systems Thinking in Schools Institute has fostered a community of systems thinking teachers and administrators that have found innovative ways to engage students in drawing and explaining connection circles, developing deeper understanding through behavior over time graphs, and fostering appreciation for sustainability through a systems framework. The teachers and administrators in St. Louis have focused on providing students with the tools to become systems citizens and subsequently better problem solvers in their classes and social communities. They emphasize that systems thinking cannot be used incorrectly, students just need the opportunity to find the relevance these tools hold for their own lives.

Unfortunately, the environment around systems thinking in St. Louis is rather actor-dependent, as this movement's development in recent years has depended heavily on the immediate presence of experts in the field and teachers with years of experience to initiate and survive. These actors in the community will not be around indefinitely, so there is a critical need to understand what factors determine the thriving or diminishing of these movements over time.

Over the past several years, the connection between Ritenour School District and the Social System Design Lab at Washington University in St. Louis has been a multiplier for the impact of the movement in terms of engaging students and training teachers. The Waters Foundation has also supported movements nationwide as they have gained capacity over the first several years. The scale-up in the number of teachers using systems thinking in the classroom at Ritenour resulted from the initial buy-in of several teachers evolving into a district-wide movement supported by many teachers and administrators. This bottom-up trend of scale-up is encouraging for districts that wish to start their own systems thinking movements but lack current capacity to do so.

The systems thinking movement at Ritenour High School began with the school principal engaging a group of student leaders in understanding the rise in behavioral issues through a systems lens. In the past, the behaviors had been addressed directly with disciplinary action, but the principal and guidance counselors wanted to understand the deeper underlying issues behind the behaviors taking place. With the students' help, administrators identified means of reducing tension within the Ritenour community surrounding relationships, levels of expectation from teachers and parents, and overall social tension. After this initial engagement of students using systems thinking tools, the professional development practices at the school also changed. Teachers were given the option to receive training in systems thinking tools to supplement their current classroom practices. Over the past several years, systems thinking has been met with significant buy-in on the part of several teachers that share their experience with peers, gradually increasing the number of classrooms where systems thinking tools are taught and employed to supplement existing material. While many teachers have yet to buy in to the relevance systems thinking has for students, the administration at Ritenour hopes for there to be a scale-up in the use of systems thinking in math and science classrooms along with a general increase in the number of teachers using systems thinking in their classrooms.

One of the biggest barriers to scaling up the number of teachers using systems thinking in the classroom is building understanding around systems thinking as an instructional tool to supplement curriculum, not a technique to replace teachers' prior practices. There are early learning outcomes for students using systems thinking tools that support augmenting current practices. Students are better problem solvers, can better support arguments and conceptualize problems, and are more engaged in the classroom. These outcomes are not hard to measure, but they have not been measured before. Regardless of these outcomes, many teachers are resistant to changing their techniques. Over time, Ritenour School District hopes to emphasize the use of systems thinking tools to the extent that the district can serve as a model for other schools and districts looking to improve learning outcomes for students. Administrators and educators at Ritenour hope for systems thinking to become a part of the lexicon for their students and educators in the future.

In several of the interviews I conducted, teachers and administrators mentioned the need for administrative buy-in and support for the value of systems thinking in the classroom. One interviewee argued that administrative buy-in is a limit to growth on the number of teachers using systems thinking in the classroom. The development of systems thinking movements is typically rather personality dependent, and as a result, having engaged and enthusiastic administrators that support increasing capacity for systems thinking in schools is a huge advantage for schools and districts.

At Maplewood-Richmond Heights Middle School, also in St. Louis, students learn systems thinking tools in the classroom and in the experiential learning aspects of their school day. Whether through observing the interior beehive, the aquaponics garden, or the school garden, students interact with natural systems every day that reinforce what they learn in the classroom. Through causal loop diagrams and behavior over time graphs, students are learning about the food production system in the United States and how their decisions around food determine broader systemic implications. Much of the use of systems thinking in the classroom at MRH is due to significant administrative support from superintendents and principals along with buy-in from teachers in various disciplines.

One of the major themes I identified throughout my conversations was the lack of measurement and analysis of learning outcomes with systems thinking in schools. Systems thinking is so often intertwined with other practices within the classroom that it is difficult to quantify impact and find evidence of improved learning outcomes. As a result, many communities do not see the value these tools provide for students, as they are not yet measurable. While experts and educators are looking into measurement tools in future years, many of the individuals I interviewed argued that the effects of systems thinking do not need to be proved, rather they are readily evidenced through interactions with students that have received the tools and skills they need. According to those I interviewed, many communities looking to start systems thinking movements struggle with this need for measurement and evaluation faced by educators nationwide.

Based on all of my interviews and literature reviews, I developed a more substantive understanding of the situation as it existed in the past and will evolve in future years. My model relies heavily on stories and theoretical parameters identified by relevant stakeholders at various levels with varying years of experience.

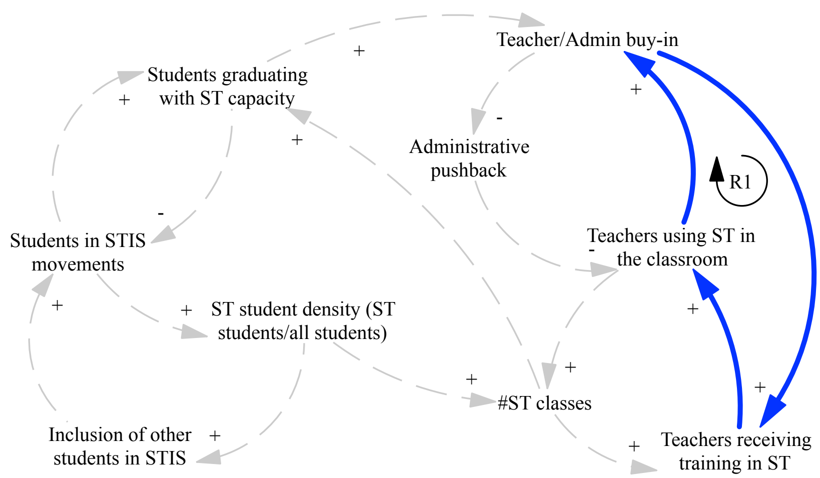


Figure 3: Training and Buy-In

In my model, I show that as a greater number of movements are formed and become established through increased capacity, we can expect more teachers in school communities to be trained in and exposed to systems thinking through diffusion of best practices and experience. As is seen in the loop within Figure 3, with a greater number of teachers engaged in the systems thinking movement, we can anticipate an increase in the amount of buy-in within schools looking to start systems thinking programs. This "buy-in loop" captures the necessity for administrative and educator investment in the implementation of Systems Thinking In Schools before potential programs can begin to develop their capacities.

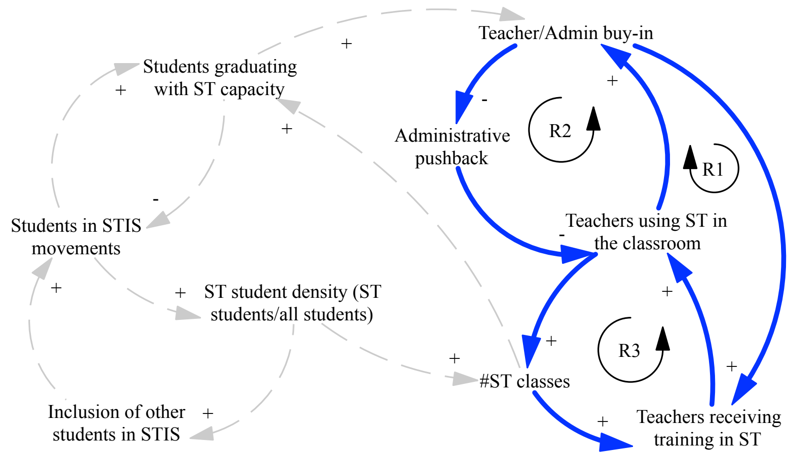


Figure 4: Buy-In and ST Classes

Without sufficient support on the part of the administration and sufficiently trained educators, the number of classrooms using principles of systems thinking has been shown to gradually diminish and oftentimes be replaced with prior classroom practices. This dynamic is captured in Figure 4. With more trained teachers, there is more experience within the community surrounding the use of systems thinking tools and the application of these tools in different classroom contexts. As a result, fostering the support for systems thinking in the classroom is easier and typically more successful than without sufficient training. The relationship between training and buy-in is a reinforcing one with more training resulting in increased support therefore increasing buy-in on the part of teachers and administrators.

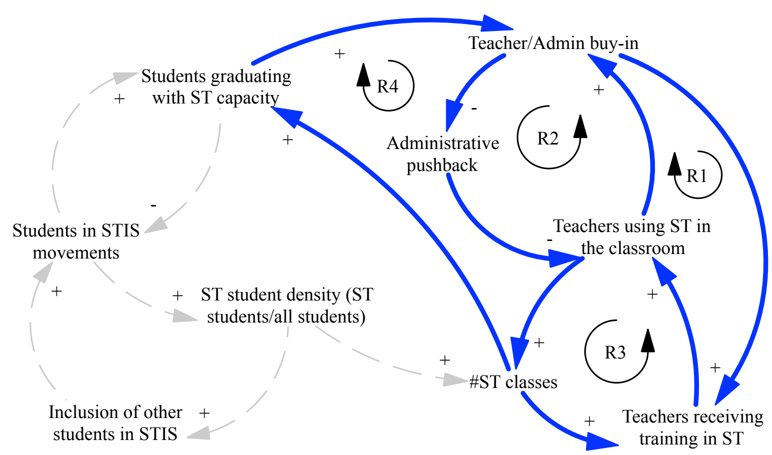


Figure 5: Students Graduating with ST Capacity and Teacher/Admin Buy-in

A major factor in the final simulation model was the relationship between students graduating with systems thinking capacity and the amount of teacher/admin buy-in to systems thinking movements. As in seen in Figure 5, with an increasing number of students learning systems thinking tools and their applicability for their lives, there was an increase in the amount of buy-in administrators and teachers had for the movements in schools. Students have graduated with improved abilities to solve complex problems and present their opinions, and while the outcomes of systems thinking supplemented curriculum are not measured, the evidential benefits of these movements are obvious. These benefits for students have further engaged administration in the support of teachers using systems thinking, and subsequently a higher number of classes in which systems thinking tools are being taught.

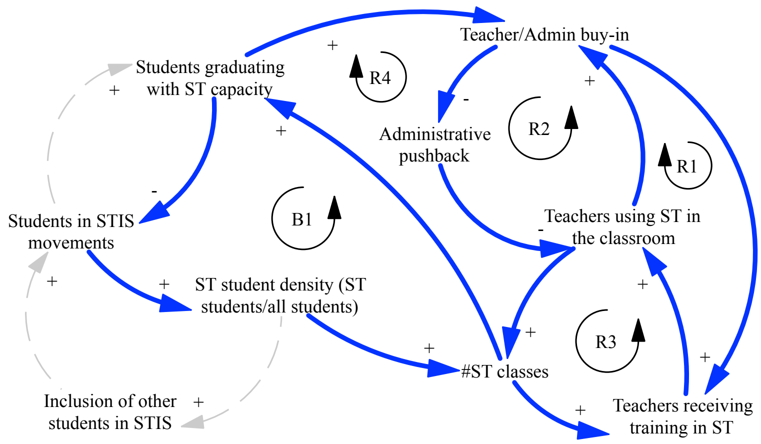


Figure 6: ST Student Density and Number of ST Classes

As is shown in Figure 6, the relationship between the number of students within the Systems Thinking in Schools program is shown to affect the "ST Student Density" (given by ST Trained Students/ all students) as it comes back to affect the number of incoming students. As the number of students in the STIS movement increases, the ST Student Density increases, subsequently increasing the number of classes in which systems thinking tools are taught and used. When there are a greater number of classes in which systems thinking tools are used, more students graduate with systems thinking capacities.

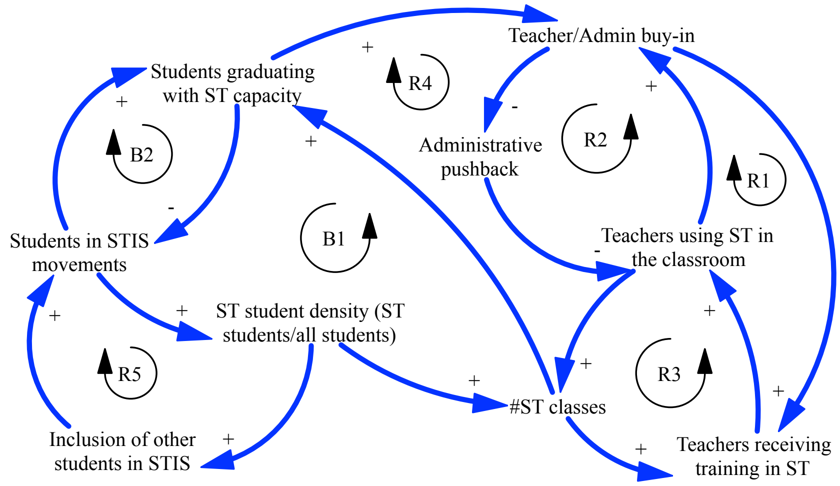


Figure 7: Inclusion of Other Students in STIS

With more students in the school community participating in the Systems Thinking In Schools movement, it can be expected for more students to ask to participate. This is due in part to increased teacher capacity needed to support more students learning systems thinking out of all students, and it is also attributed to an increased number of students sharing their systems thinking capacities with peers. Once students interact with their peers and learn about the relevance that systems thinking tools hold for their lives, many more want to join the systems thinking movement.

6. Simulation Structure[2]

After several iterations and restructurings of the previous simulation structures, I arrived at the final framework and started to develop model insights and conduct model analysis. There are several smaller structures within the final simulating structure that are worth explaining and clarifying.

[2] See Appendix I for full simulation structure

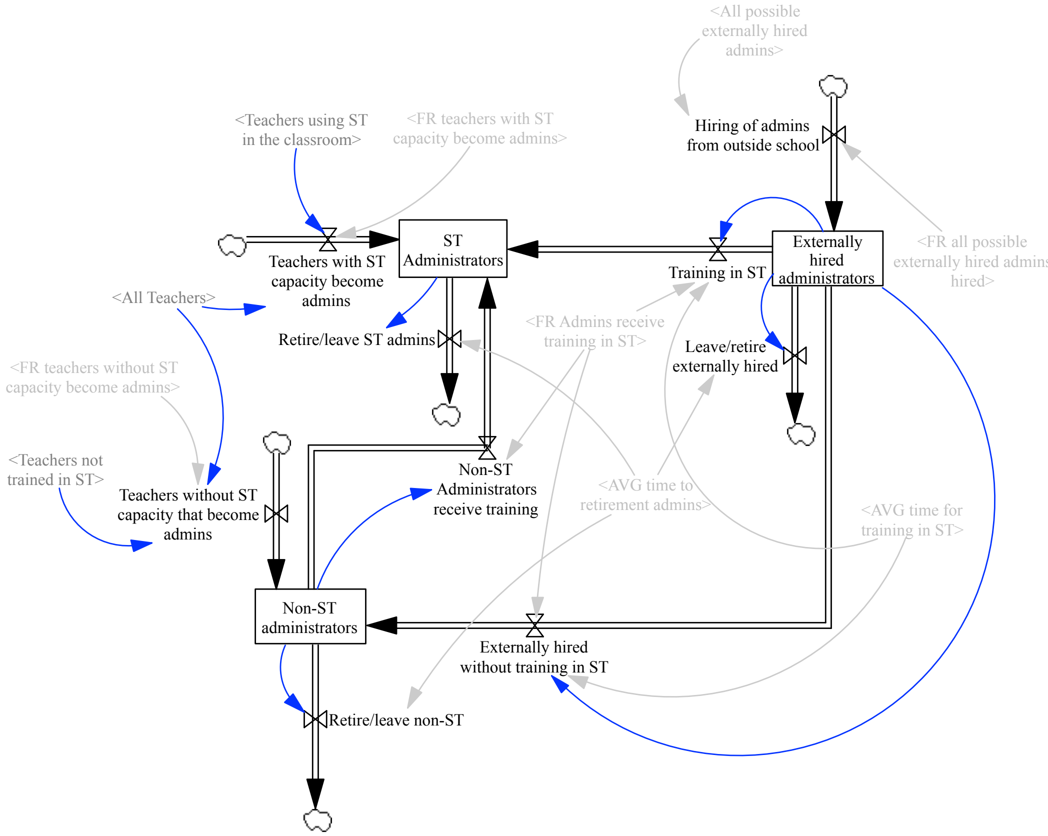


Figure 8: Administrator Structure

This structure in Figure 8 captures the different means by which administrators can be hired, gain experience learning or being trained in systems thinking, and leave the district or retire. After consulting with mentors and interviewees, I concluded it was vital to capture the different paths administrators could be hired (internally or externally), transition towards being systems thinking administrators (through past experience, immediate training, or training after several years), such that the quotient of systems thinking-trained administrators could come back to impact the teacher-administrator buy-in ratio. One of my mentors and I agreed that administrators hired internally (from the teacher base within the district) would have a higher propensity towards using systems thinking and have greater support for the movements because of prior exposure and potentially prior experience teaching systems thinking in the classroom.

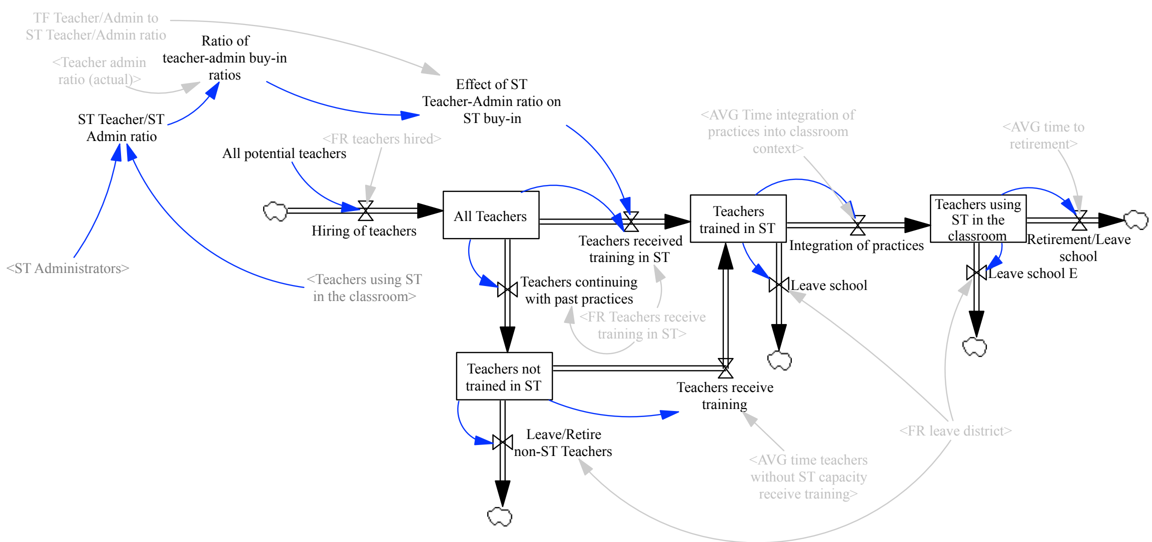


Figure 9: Teacher Structure and Teacher-Admin Table Function

This portion of the final structure in Figure 9 captures the transition of teachers within the district from using their old practices to supplementing those practices with systems thinking tools and activities. The use of a teacher-admin buy-in ratio captures the input of several interviewees that discussed the issues surrounding scale-up of the number of teachers using systems thinking in the classroom. These interviewees perceived that administrative buy-in was a limit to growth for systems thinking in the classroom. While significant investment and buy-in on the part of the teachers is vital, there is a need for significant buy-in on the part of superintendents and principals to facilitate rapid scale-up and district-wide emphasis on the importance of systems thinking tools for students. To capture this issue, I built a table function that takes the ratio of teachers using systems thinking to the number of administrators with systems thinking capacities and divides it by the actual teacher to admin ratio. Using this formulation, the value fluctuations from less than one to greater than one. When the value is less than one, the number of administrators with systems thinking capacity and buy-in is greater than the number of teachers with buy-in, causing a multiplying effect for the number of teachers that receive training in systems thinking tools. When the value is greater than one, there are a greater number of teachers with buy-in than administrators, which results in a greatly diminished effect of buy-in on the number of teachers receiving systems thinking training over time. With this table function and ratio formulation, the simulation achieved behavior shown in the reference mode.

7. Simulation

After conducting thorough model analysis through extreme conditions tests and attempting to set the model in equilibrium, I began simulating the structure using a variety of potential policy tests. During parameter testing, most of my tests indicated that the model was robust and producing feasible behaviors. In several instances, the model produced results that were undefined and infeasible. As such, I plan to iterate upon the current structure and potentially rebuild it to eliminate these unreasonable findings.

With respect to simulation results, many of the stocks achieved the desired goal-seeking behavior (Figure 10a), but others produced overshoot and collapse behavior (Figure 10b). I am identifying now which parametric values produce the desired results shown in the reference mode, rather than indications of feared behavior. It is interesting to note, however, that the parameters I have included, which were confirmed in interviews and research, show the overshoot and collapse behavior for the number of teachers using systems thinking in the classroom, which has shown to be the trend in reality.

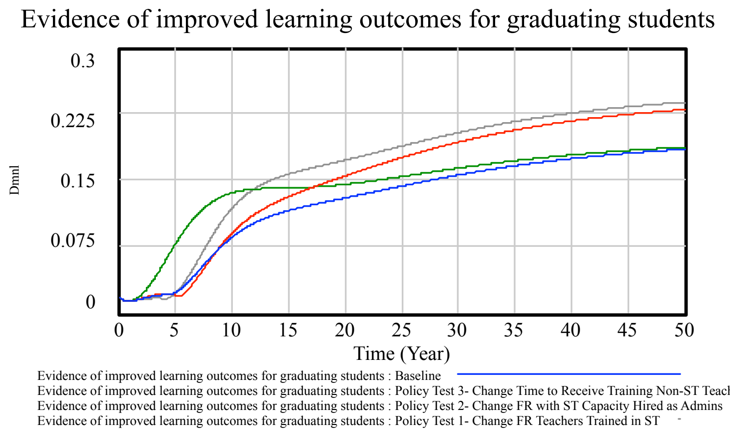


Figure 10a: Evidence of Improved Learning Outcomes for Graduating Students

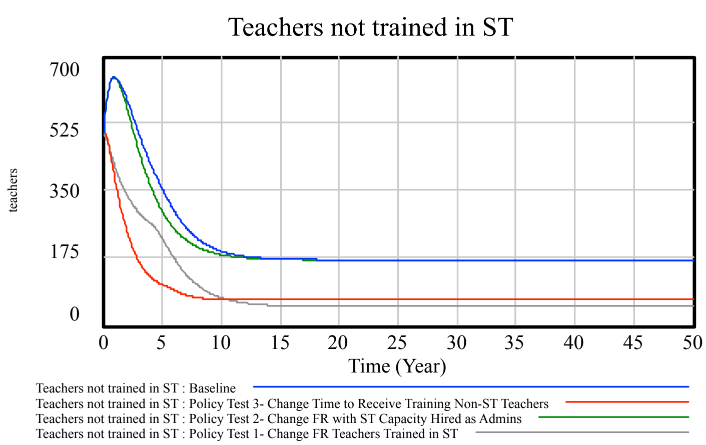


Figure 10b: Teachers not trained in ST

Because the desired behavior focused on increasing the percentage of teachers using systems thinking in the classroom, I focused mainly on affecting parameters close to the stock “Teachers using ST in the classroom”. These policy tests, described in depth later, produced behavior indicative of behavior shown in the reference mode, Feared 1. Based on these findings, the parameters and structure employed are not producing the desired behavior, and as such, more work must be done to understand how desired behavior can be produced through model structure.

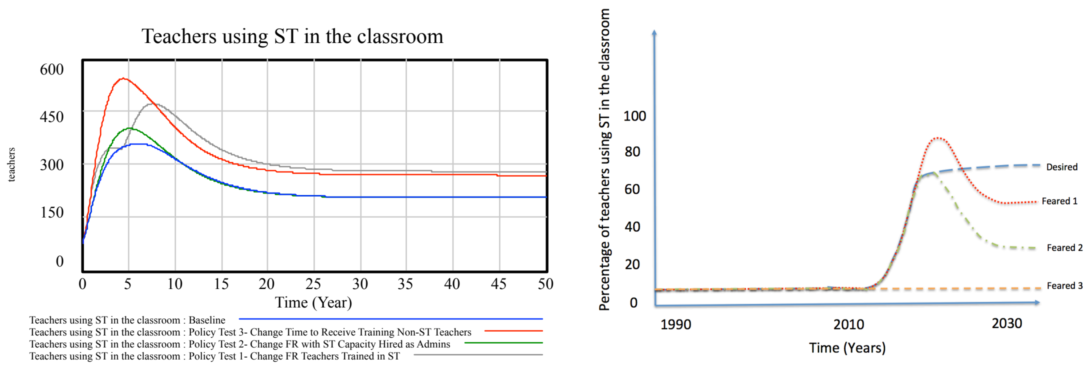


Figure 11: Simulated Behavior vs. Desired Behavior of Reference Mode

Although these results indicate undesirable behavior for scaling up the percentage of teachers using systems thinking in the classroom, it is worth noting that the percentage of teachers does in fact increase over time. This is positive for increasing the percentage of teachers using systems thinking, but the manner by which this percentage increases is unsustainable

8. Potential Leverage Points and Insights

Over the course of conversations with stakeholders and mentors, I began to identify several leverage points around scaling up the number of teachers using systems thinking in the classroom. Many of these were parametric changes rather than structural interventions, and I plan to conduct more intensive tests around changing structure to identify more robust, higher impact leverage points for the system.

The first policy test, shown in the graphs in grey, entailed shifting the fraction of all teachers receiving training in systems thinking from 25% to 80%. By increasing the percentage of teachers receiving training in systems thinking, a larger number of teachers have the foundations of expertise to share with peers and find relevancy for their respective classrooms. Over time, it is expected for the number of teachers trained in systems thinking to identify means of applying the tools to their classroom environments.

The second policy test, shown in green, entailed raising the percentage of teachers with systems thinking capacity internally hired as administrators from 5% to 10%. With a higher number of teachers with systems thinking capacities being internally hired for administrative roles, I anticipated an increase in the amount of buy-in within the community. Teachers have experience with their students seeing evidence of improved learning outcomes from systems thinking tools, and they carry that insight into their roles with the administration where they have the potential to foster more support for the movements at a different level and scope.

The third and final policy test, shown in red, resulted from changing the average time for training of non-systems thinking teachers from four years to one year. With this change, it is required to change the norms emphasizing the value of systems thinking in the classroom. With this increase in community level support for the importance and relevance of systems thinking for students, I anticipated increases in the number of students graduating with systems thinking capacities and the number of teachers using systems thinking in the classroom.

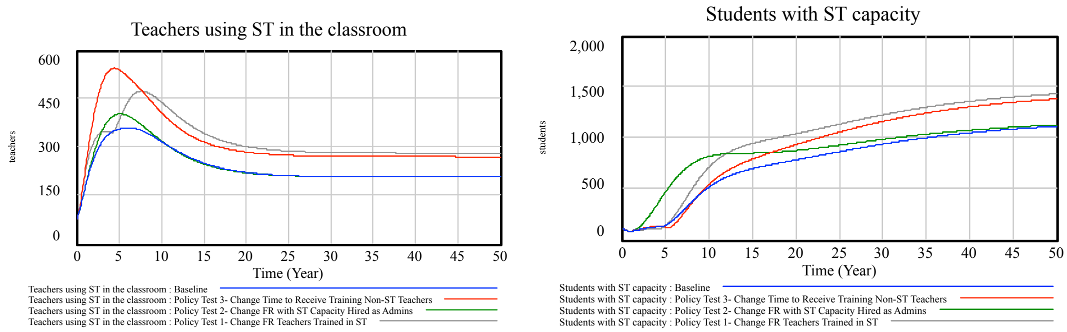


Figure 12: Teachers Using Systems Thinking in the Classroom and Students Graduating with ST Capacity

After running the series of policy simulations, I identified several variables of interest within the simulation structure. With the reference mode focusing mainly on the increasing number of teachers using systems thinking in the classroom, I expanded the range of focus to observing the effects of policies on students and administrators. Based on the above findings in Figure 12, the policy shown to most affect the number of teachers using systems thinking in the classroom and the number of students with systems thinking capacities is the first policy: to increase the percentage of teachers receiving training in systems thinking. These results are intuitive as this fractional rate of teachers receiving training is integral to the teacher structure shown earlier in Figure 9. The second most impactful strategy is the third policy test, decreasing the time for non-systems thinking teachers to receive training in systems thinking. Both the first and third policy tests affect the number of teachers trained in systems thinking tools. This affects the teachers' subsequent transition to using systems thinking in the classroom over several years of finding relevancy and applicability to their existing classroom practices.

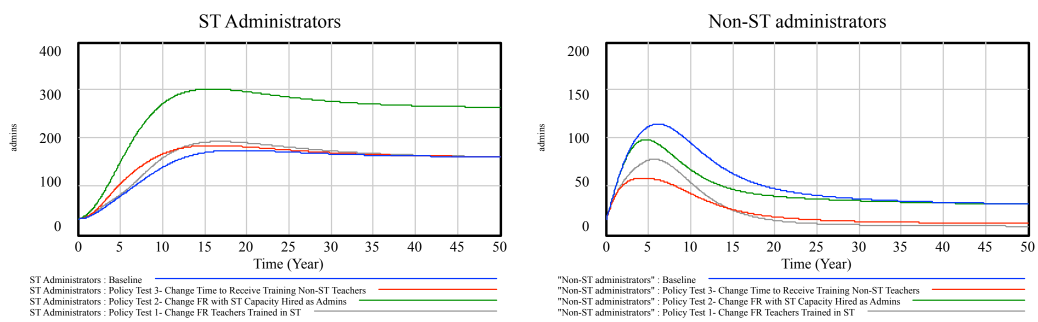


Figure 13: ST Administrators and Non-ST Administrators

In regards to increasing the percentage of teachers using systems thinking in the classroom hired internally as administrators, the most impact was seen with the increase in the number of systems thinking administrators over time. Shown in Figure 13, with an increase in the percentage of teachers with systems thinking capacities hired to serve as administrators, the number of systems thinking administrators increases rapidly and sustains itself over the time horizon. As is hoped with this increase in systems thinking administrators, the number of non-systems thinking administrators decreases over time. While this second policy test had a significant impact on the number of administrators with systems thinking capacities, similar impact is not seen within the stocks of teachers and students with systems thinking capacities. This finding provides insight that increasing the number of systems thinking administrators over time may foster a rapid increase in the number of students and teachers learning systems thinking, but more sustained growth in the number of teachers using systems thinking in the classroom must result from a higher percentage of all teachers receiving training in systems thinking tools.

Based on these results of the policy test simulations, I conclude that for a significant increase in the number of teachers using systems thinking in the classroom, increased training capacity for teachers is most vital. As such, I propose for school communities to develop training capacity such that a greater quotient of the teachers can find applicability and relevancy of systems thinking for their classrooms and their students.

9. Limitations to the Structure

Because many teachers utilize principles of systems thinking and system dynamics modeling in the classroom while functioning independently of supporting organizations such as the Waters Foundation and Creative Learning Exchange, it is difficult to quantify the number of teachers practicing systems thinking in their classroom. As a result, many of the parameters in these models are hypothetical values based on interviews with experts and reviews of literature surrounding the field of applying systems thinking in the classroom.

In the same vein, it is difficult to quantify the number of teachers using systems thinking at a given time, due to the randomness by which teachers use systems thinking tools, gain more expertise through training and interactions with teachers already using these tools, and abandon the use of systems thinking when they cannot find usefulness for it in the classroom. As such, this model is too simple to capture the stochastic transitions of teachers between using and not using systems thinking. After consulting with mentors and experts, I have concluded that using an agent-based framework to inform fluctuations in the number of teachers using systems thinking is a productive next step. By simulating the means by which different teachers interact and disseminate their practices and experience, I can more effectively capture the different transitions teachers make between not using and using systems thinking tools.

Another issue that is not captured are the different propensities certain educators and administrators have towards using these tools in the classroom. Some people have natural inclinations towards using systems thinking based on their learning styles and personalities. This aspect of the situation is not captured effectively with the current model structure, and more work must be done through qualitative research to understand how these inclinations are observed in the real world.

Along with uncertainty associated with the number of teachers and administrators using systems thinking tools, there is uncertainty associated with the proposed learning outcomes of systems thinking as they foster teacher and administrative buy-in within a community. The learning outcomes of systems thinking have yet to be measured, and this has created a dichotomy between communities of people that need data to support a program or classroom technique and those that have faith in the benefits systems thinking can provide for students. Once measurement tools are available and begin to identify specific learning outcomes of systems thinking and the number of classrooms where systems thinking is used, this model can be better substantiated with real-world data.

10. Model Assumptions

Many of the assumptions within this model have to do with the transitions of teachers and administrators from not using or being trained in systems thinking to become systems thinking administrators and teachers. The transitions assume that everyone goes through the same transitions and learning processes, which is not entirely representative of the randomness by which many teachers begin using systems thinking tools with their students. This model also assumes that systems thinking in the classroom is being encouraged and implemented on a district-wide level, which is not necessarily representative of all communities looking to include systems thinking in their curricular practices. Some communities teach systems thinking tools on a class-by-class basis, some use the tools for extracurricular projects and programs, and others integrate them into every aspect of a student's life. What is happening at Ritenour School District and Maplewood-Richmond Heights School District in St. Louis, Missouri is not entirely representative of all movements happening locally or nationwide.

11. Next Steps

As this model is expanded and integrated, there is a need to construct a case study around the systems thinking movements in St. Louis and other communities as they highlight the best practices and difficulties of starting and maintaining strong movements. There also needs to be input from systems thinking movements that have not thrived at the same level to inform the issues of diminished capacity and program scale-back. Evidence from literature, qualitative interviews, and input from relevant stakeholders will provide insight for a model that more effectively reflects stakeholder perceptions.

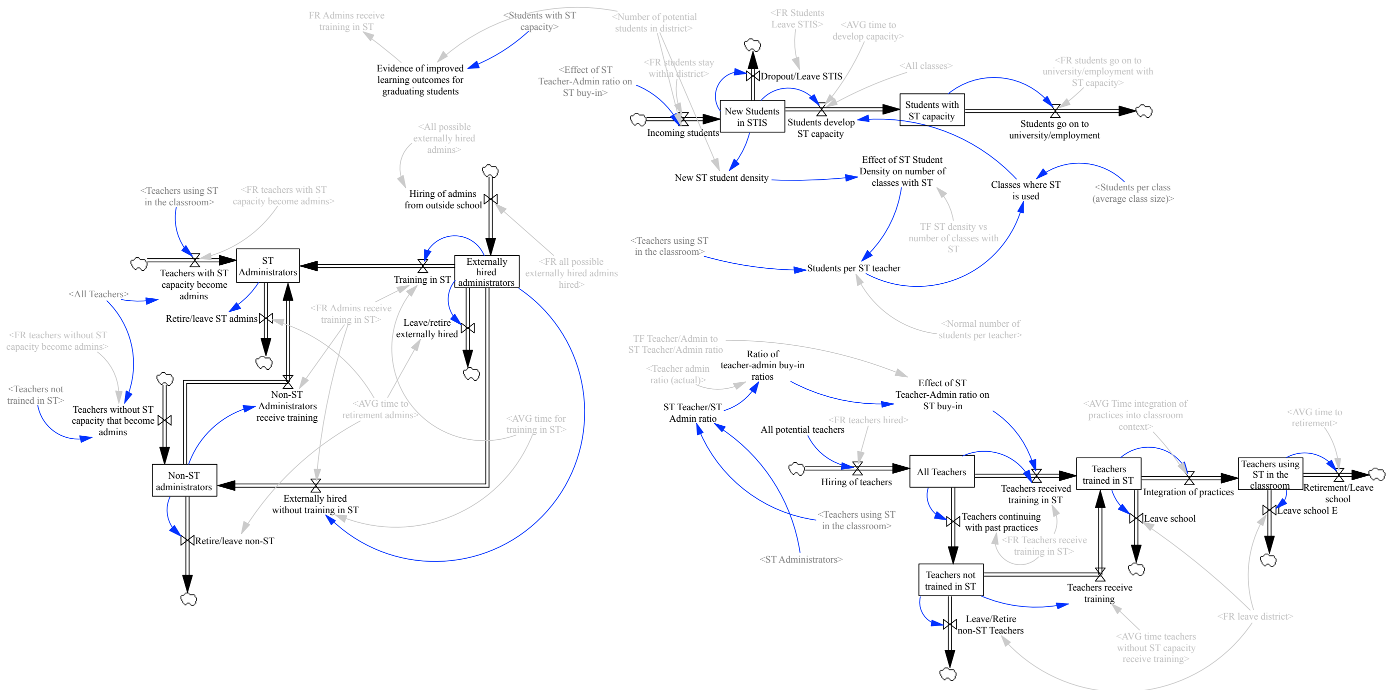
What are the steps and action plans potential communities can take to better foster systems thinking movements? What interventions are remotely relevant and successful in a given context? It is hoped that the findings from this research can be disseminated to teachers and administrators in communities nationwide such that a greater number of students can experience systems thinking and its proposed beneficial learning outcomes for themselves. There needs to be further research pertaining to the implementation of innovative programming in public and private schools through further review of literature and qualitative interviews with relevant stakeholders.

12. Impact and Measurement

Because the evidence of systems thinking learning outcomes is relatively limited in scope and breadth, this project is studying some very pioneering work. Many of the programs I am studying are in their infancy or pilot programs in their communities. While the benefits to be derived from a more interactive, experiential learning process are challenging to quantify, I am confident that it will be possible to measure success in these programs.

The collection of data, qualitative and quantitative, will come from further literature reviews of resources available through the Waters Foundation about Systems Thinking in Schools, resources available through the Creative Learning Exchange's website, interviews with stakeholders at the administrator, educator, and student level, along with research surrounding implementation of innovative programming in public and private school contexts.

The purpose of this project is to grasp the potential impact of systems thinking programs and supplemented curriculum as they equip youth to better tackle complex problems in their academic and social lives. These programs are developing capacity in youth, educators, and community members to better address complex problems using visualization and simulation tools. Systems thinking has the potential to completely transform the classroom experience, but before that dream can be realized, we must do more work to understand what makes programs successful and sustainable.



Appendix I: Simulation Structure

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