QUALITY AND SYSTEM DYNAMICS/SYSTEMS THINKING: INTEGRATING THEM IN A MIDDLE SCHOOL

BY
JOAN YATES

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SUMMARY

The quality movement in this country has heretofore taken place primarily in business and industry. Within the past five years or so, however, an increasing number of educators have been thinking, speaking and writing about applications of quality principles, particularly those espoused by W. Edwards Deming, in schools. Educators have also fairly recently been investigating ways to incorporate some of the thinking and practices from the fields of system dynamics and systems thinking, both previously applied more in the domains of business and post-secondary education than in K-12 education, into classrooms and into the running of their schools and school districts.

Staff members at Orange Grove Middle School in Tucson, Arizona, have been integrating some of the key practices and principles of total quality, system dynamics, and systems thinking within their school for the past five to seven years. The author provides examples of applications of this integration within an eighth grade writing and literature class and within the organization of the school.

INTRODUCTION

As a staff member at Orange Grove Middle School of the Catalina Foothills School District in Tucson, Arizona, and as the manager of the district's System Dynamics Project, I have participated in the implementation of programs and practices within the last five to seven years that integrate principles of quality with principles and tools of system dynamics (SD) and systems thinking (ST). Originally, we at Orange Grove did not actively seek out the writings, input, or influence of some of the leading thinkers in these fields–W. Edwards Deming, Jay Forrester, Barry Richmond and Peter Senge–but have nonetheless over time created, adopted, and revised structures and practices that represent an integration of some of the principles of each field.

In the spring of 1988, two events happened concurrently in our school district. One was the decision to transform Orange Grove from a junior high into a middle school. The other event involved community member, and Dean Emeritus of MIT's School of Engineering and Institute Professor of the Department of Electrical Engineering, Dr. Gordon S. Brown's sharing of the STELLA® software (Richmond, Peterson et al, 1988) with eighth grade science teacher Frank Draper. Unbeknownst to us at the time, the combination of these two seemingly unrelated events proved to be a major catalyst in the formation of what is now a middle school that applies many of Deming's fourteen principles (Blankstein, 1992, 71) and four components of profound knowledge (Rhodes, 1990, 34), Jay Forrester's and Barry Richmond's work in the field of system dynamics, and Peter Senge's concept of the five disciplines of a learning organization, particularly the fifth discipline of systems thinking.

DEMING'S QUALITY PRINCIPLES AT ORANGE GROVE

Over the years, the Orange Grove staff has never undertaken a study of, or even a discussion of, Dr. Deming's work. Having said that, though, I must emphasize that what we are doing, and have done over the years, is work to create constancy of purpose for improvement of product and service; improve constantly and forever every process; institute training on the job; adopt and institute leadership; drive out fear; break down barriers between staff areas; eliminate slogans, exhortations, and targets for the staff; remove barriers that rob people of pride of workmanship; institute a vigorous program of education and

self-improvement for everyone; and put everybody in the organization to work to accomplish desired transformation (Blankstein, 1992, 71)–ten of Deming's fourteen principles.

There are specific actions and/or structures that we as a community of staff, students and parents have instituted over the years to implement each of the principles, but within the scope of this paper and its topic of integrating quality principles with system dynamics and systems thinking, I will focus particularly on the principle of breaking down barriers between staff areas. (If you are interested in learning more about philosophy and practices at Orange Grove that I believe are consistent with Deming's principles, you can consult Structuring Schools for Success...A View from the Inside, Vol. 11 of the Total Quality Education for the World's Best Schools series, a book written by my Orange Grove colleagues Mary Scheetz and Tracy Benson about work done there in the past five years.) (Scheetz and Benson, 1994)

In addition to the ten listed principles, the OG community incorporates Deming's systems component of profound knowledge–"Deming believes organizations are systems whose 'functions or activities work together for the aim of the organization,' " (Rhodes, 1990, 34) as well as his "PDSA (Plan-Do-Study-Act) cycle" (Schmoker and Wilson, 1993, 392) into our work, as I will elaborate on in the "Quality and ST in the Organization" and "Quality, SD and ST in the Classroom" sections of this paper, respectively.

SYSTEM DYNAMICS AT ORANGE GROVE

From the moment Dr. Gordon Brown stepped onto the Orange Grove campus to talk with Frank Draper and share the STELLA® program, we at Orange Grove have been learning about and applying our knowledge of system dynamics, both within the classroom with students and as staff members working together within a learning organization.

System dynamics is a field created by Dr. Jay Forrester, who had been a graduate-student staff member at the MIT Servomechanisms Laboratory under Dr. Brown's directorship in the early 1940's.

In Dr. Forrester's words,

> System dynamics provides a way to understand how things change through time. Most problems and their solutions involve change...System dynamics is more than a set of tools. It provides a philosophy and a way of looking at the world to understand better how the past led to the present and how present actions control the future. But system dynamics goes much deeper than just talking about systems. It builds on the strength of people's experience and knowledge. System dynamics compensates for the major weakness in customary decision making by showing how the pieces of the system that we know about are producing the behavior that is so puzzling. Such greater understanding comes from organizing our knowledge of the parts into computer simulation models that allow observation of how the parts interact...System dynamics provides a dynamic framework into which students can place detailed knowledge. (Forrester, 1994)

Since 1988, students and staff at Orange Grove have built and/or run computer simulation models that facilitate study of how parts of various social, biological, and environmental systems interact. In addition to computer models, we have used other system dynamics tools to show, among other things, how the pieces of the system that we know about are producing behavior that may be puzzling us. (Forrester, 1994) In the "Quality, SD and ST in the Classroom" section of this paper, I will elaborate on the use of the SD tool known as a behavior-over-time graph (BOTG) in an 8th grade writing and literature class, and how the use of this tool was integrated with a variation of Deming's PDSA cycle, as students worked to improve their individual performance in class.

SYSTEMS THINKING AT ORANGE GROVE

The terms "system dynamics" and "systems thinking" are inextricably linked. In his paper "Systems thinking/system dynamics: let's just get on with it," Barry Richmond (1994), one of the creators of the STELLA® software, attempts to clarify what system thinking is and is not. As for what systems thinking is not, Richmond says,

> Let me begin by briefly saying what systems thinking is not. It is not General Systems Theory nor soft systems nor systems analysis, although it has elements in common with all of these. Furthermore, systems thinking is not the same as chaos theory, dissipative structures, operations research, decision analysis, or what control theorists mean when they say system dynamics, although, again, there are similarities in subject matter and methodology. Systems thinking is also not hexagrams, personal mastery, dialogues, or total quality. (Richmond, 1994)

Richmond goes on to state what systems thinking is.

> The definition of *systems thinking* at which I have arrived is the following: systems thinking is the art and science of making reliable inferences about behavior by developing an increasingly deep understanding of underlying structure. (Richmond, 1994)

Peter Senge, in his book The Fifth Discipline: The Art and Practice of The Learning Organization, describes systems thinking in this way:

> The essence of the discipline of systems thinking lies in the shift of mind:
> - seeing interrelationships rather than linear cause-effect chains, and
> - seeing processes of change rather than snapshots
>
> The practice of systems thinking starts with understanding a simple concept called "feedback" that shows how actions can reinforce or counteract (balance) each other. *It builds to learning to recognize types of "structures" that recur again and again*...Eventually, systems thinking forms a rich language for describing a vast array of interrelationships and patterns of change. Ultimately, *it simplifies life* by helping us see the deeper patterns lying behind the events and the details. (Senge, 1990, 73)

A common component of Richmond's and Senge's definitions of systems thinking involves identifying and understanding underlying structure. In our case at OG, we have looked at the interrelationship of parts and the underlying structures of the system both within a classroom and within the organization that is the school. Having done some of the initial identification of interrelationships and structure, and having some understanding of the underlying structure that is in place, we have gone on in many instances to examine whether the structures that are in place are helping us achieve our desired results. When we've found that certain structures aren't helping us, we have then worked to determine what structures we think are most likely to facilitate our achieving the desired results, keeping in mind both short-term and long-term effects of potential changes in infrastructure.

INTEGRATING THE PRINCIPLES OF THE THREE FIELDS

Deming's, Forrester's, Richmond's and Senge's thoughts overlap, particularly as they emphasize the importance of identifying the parts of a system in which you are working, or which you are studying, and recognizing the interrelationships of those parts and the behavior generated as a result of those interrelationships.

Although Deming is primarily associated with the "quality movement" and his 14 principles, his thoughts about systems as one of the four components of profound knowledge provide the link between Forrester's, Richmond's and Senge's systemic view of the world and Deming's belief about the systemic nature of an organization**:**

> Management of a system requires knowledge of the interrelationships between all the components within the system and of the people who work in it...The greater the interdependence between components, the greater the need for communication and cooperation between them...All the people that work within a system can contribute to improvement, and thus enhance their joy in work. (Rhodes, 1990, 34)

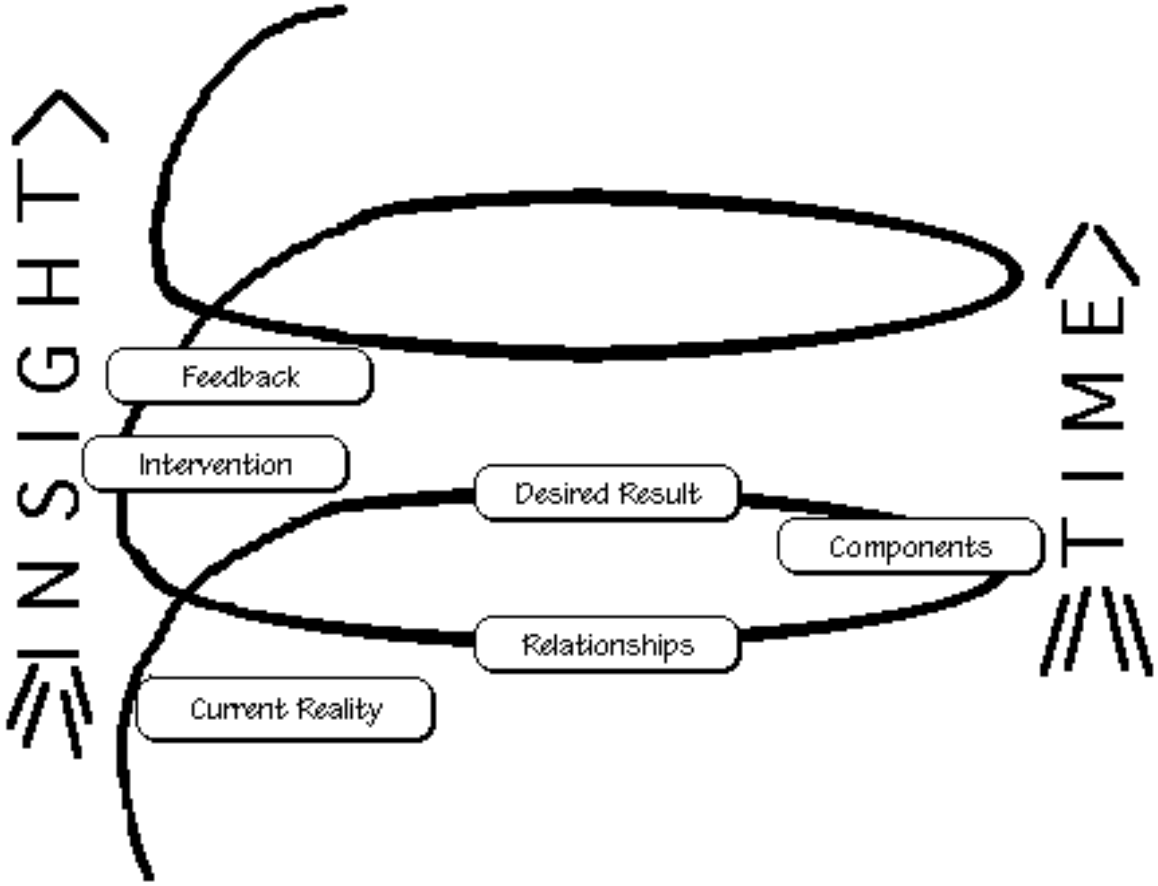
Dr. Deming's statements illustrate the advantages of working together productively within a system–enhancing one's joy in work–as well as some of the challenges presented by taking a systems view of a working or learning situation–a greater need for communication and cooperation. What is left to us at Orange Grove and to practioners in all organizations who believe in the principles of quality, system dynamics and systems thinking, is to find ways to incorporate those beliefs into our daily work.

QUALITY, SD AND ST IN THE CLASSROOM

One example of the melding of quality principles and system dynamics within a class at Orange Grove comes from Ron Michalak's eighth grade writing and literature class. Mr. Michalak and I, neither of whom was familiar with Dr. Deming's work at the time but who both had been members of the Orange Grove staff throughout the years in which we've been learning about and implementing SD and ST, created an adaptation of Deming's Plan-Do-Study-Act cycle (Schmoker and Wilson, 1993, 392) four years ago which we called Slinky® Theory©, referencing the name of the popular Slinky® toy**.** Michalak uses Slinky® Theory© with his students/has his students use applications of the theory throughout the year in a variety of ways.

The theoretical basis for Slinky® Theory© is Forrester's/SD's "a way of looking at the world to understand better how the past led to the present and how present actions control the future," (Forrester, 1994) as well as Senge's/ST's "seeing relationships rather than linear cause-effect chains, and seeing processes of change rather than snapshots." (Senge, 1990, 73) Michalak and I wanted to illustrate to a group of adults with whom we were working that a person or group of people never covers exactly the same ground when repeating the process of observing current reality; determining desired results; identifying components of the system in which the work will be done and the relationships between those components; acting, or performing some intervention; getting feedback and/or seeing how feedback within the system affects the outcome of the actions taken; and then beginning again by observing what the new current reality is after having gone through one "loop" of what we believed to be a circular cycle. (Note the parallels between these steps of Slinky® Theory© and Deming's PDSA cycle.) Being teachers who appreciated the value of "visuals," we hit upon using the Slinky® I had at home as a physical representation of a continuous, repeated circular pattern around which you could move without covering the same ground, i.e., touching the same link of the Slinky®.

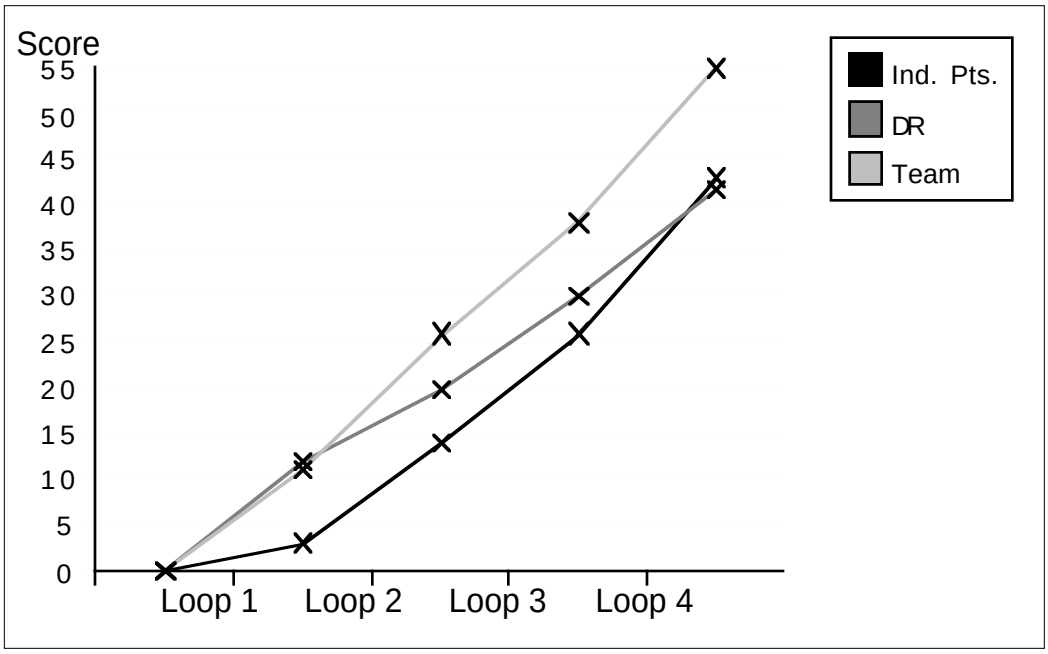
Pictorial Representation of Slinky® Theory©



One application of Slinky® Theory© in Michalak's class combined the theory with use of the SD tool behavior-over-time graph (BOTG) as the students completed a propaganda game used in the propaganda unit within the non-fiction component of the literature course. Michalak let his students know what the "desired result" was, i.e., what it would take by the end of the game to achieve a grade of "C." The students had also taken notes on what the "components" and "relationships" were in the game, and on what actions/"interventions" they could take in the game in order to score points. Then, after the students had completed two "loops" of the game, they made BOTGs on the computer by inputting their scores and the scores necessary at that point to be achieving the desired result for a passing grade. By doing this, the students were able to "see" how they were doing.

As a system dynamics tool, BOTGs are designed to help students begin to see how things change over time. By graphing their scores relative to the desired results, students could see how they were faring over time as the game progressed. Michalak's assumption was that having that feedback would improve the accuracy of each student's assessment of his/her "current reality" in the game, and would help them as they chose what their individual actions/interventions should be in the next "loop" of the game, in order to achieve the desired results by the end of the game.

An Individual Student's BOTG
(DR=Desired Result)



Michalak also used an additional intervention, along with Slinky® Theory© and BOTGs, creating another structure in the class which he felt would most likely help him achieve his desired result, which was that all students would demonstrate understanding of various propaganda techniques as shown by their passing scores in the game. The additional intervention included Michalak, myself, and Orange Grove's System Dynamics Mentor, Sam DeVore, working as personal "coaches" with students in the class who were below the desired result after the second "loop" through the propaganda game. Michalak and I put together a sheet which we three coaches would use when meeting with each student. The sheet listed information the students previously had been given about the "desired result," "components" and "relationships" intrinsic to the game and asked the students to write out the plan/intervention they would commit to trying in the next loop of the game in order to improve their performance, thereby bringing their score closer to the desired result, or perhaps surpassing the DR.

Sheet Used by Coaches with Students
Who Scored Below the DR After Two Loops

Name_____
Coach_____

Propaganda Game Relationship Analysis Sheet

Components	Points
Plurality	3
Defend	1
Challenge/good argument	2
Challenge/good argument/correct	8

Above Desired Result Scenarios for Loop 1 and 2 **total**

#1	Pluralities - 6	Defenses - 5	Challenges - 5
#2	Pluralities - 2	Defenses - 2	Challenges - 6
Yours	Pluralities -	Defenses -	Challenges -

Action Plan for Loop ____ Using your graphs and the information above, what components will you affect differently in the next loop? What will be your new intervention? Write your plan on the back of this sheet.

Michalak was deliberately using classroom structures that employed system dynamics and systems thinking in order to facilitate his and the students' achievement of desired results. What he didn't know was that he was also integrating SD and ST with some of Deming's philosophy as applied to schools:

> His (Deming) philosophy assumes an educational system in which desired outcomes are clearly defined and understood by all. The teacher's responsibility is to assist all students to improve processes toward achieving the outcomes...When problems arise, those directly involved...may form a *quality circle*. Rather than blaming any individual, they collect relevant data on the situation, define a possible opportunity to improve the process, test the change in the system, observe the results, and permanently implement the change, if it proves effective. (Sherkenbach, 1988, as quoted by Blankstein, 1992, 73)

In the case of "The Propaganda Game" in his class, Michalak established structures that would help the students and himself keep track of change over time, rather than waiting until the end of the unit to test students and give them a grade. He also provided information about the desired results at the very beginning of the unit, and created a version of quality circles that included himself, each student who was performing below the DR level, and a personal coach for each student. The interventions with the coaches began after the second loop through the game. At the end of the third loop, the coaches and students met again, and some coaches also met with individual students during loops three and four.

Using the “coaching” structure throughout loops three and four of the game melded the quality steps of “...define a possible opportunity to improve the process, test the change in the system, observe the results, and permanently implement the change, if it proves effective...” (Blankstein, 1992, 73) with the system dynamics concept of “showing how the pieces of the system that we know about are producing the behavior that is so puzzling...” (Forrester, 1994)

As one of the coaches who worked with the students, I can assure you that they were puzzled about how/why they had the scores they did at the end of the second loop, and they were equally puzzled about how they might improve their performance and, therefore, their score. Once we used the “Relationship Analysis Sheet” with them, though, the students were able to accurately analyze how their previous actions, or lack of action, had generated their current scores and the students could go on to plan a course of action for the next loop of the game that should bring their score closer to the desired result. Only one of the six students with whom we worked in Mr. Michalak’s class did not reach or exceed the DR by the end of the game, a result that far exceeded what Mr. Michalak’s students had achieved the previous year when he did not use these interventions with the students. (The results were also better in the class in which we did use all three structures–Slinky® Theory©, BOTGs, and coaching with the Relationship Analysis Sheet–than in his class in which he only used the first two structures.)

QUALITY AND ST IN THE ORGANIZATION

A major change at Orange Grove in the past five to seven years has occurred in our perception of our school/ourselves as a system,

> ...a perceived whole whose elements “hang together” because they continually affect each other over time and operate toward a common purpose. The word descends from the Greek verb *sunistanái,* which originally meant “to cause to stand together.” As this origin suggests, the structure of a system includes the quality of perception with which you, the observer, cause it to stand together...Some people think the “structure” of an organization is the organization chart. Others think “structure” means the design of organizational work flow and processes. But in systems thinking, the “structure” is the pattern of interrelationships among key components of the system. That might include the hierarchy and process flows, but it also includes attitudes and perceptions, the quality of products, the ways in which decisions are made, and hundreds of other factors. (Senge et al, 1994, 90)

As recently as school year 1988-1989, Orange Grove was a junior high school that scheduled students to see a different teacher for a different class every 45 minutes, and scheduled the teachers to have a 45 minute planning period sometime during the day, not necessarily with other teachers who taught the same subject or grade level. Under this organizational scheme, teachers came together in order to share information and make decisions in one of two basic groupings–as subject matter departments, e.g., the English department or the math department, and as a staff for whole group “faculty meetings.” We did not have structures established to facilitate communication and, by extension, interrelationships among key components of our system–we were only having small group discussions with and consistently exchanging ideas with our colleagues who taught the same academic subject we did. The only other structured communication happened between the principal and the departments, via a department head or rep. There was no scheduled interdepartment communication, and therefore that type of communication, and the collaboration that could have come about as a result of it, did not happen consistently. We hadn’t come to appreciate how interrelated we were as “components” of the system that constituted our students’ formal educational system, and therefore weren’t operating based on Deming’s thought, quoted earlier, that “the greater the interdependence between components, the greater the need for communication and cooperation between them.” (Rhodes, 1990, 34) We were definitely not viewing ourselves systemically in terms of how we were communicating.

Likewise, we stayed within the same structures when we made decisions. Teachers within any one department made curriculum and instruction decisions, as well as purchasing decisions, in isolation from teachers who taught other subjects. Staff members who were not classroom teachers were included in decisions only when something reached the stage of being a "whole school decision" that came up for a vote in a faculty meeting, unless they were responsible for an area of the school such as the library or counseling, in which case they made decisions about purchasing and policy in isolation, perhaps after consulting select colleagues, or in conjunction with the principal. The principal had the final say in most operational and budgetary decisions.

As with communication, decision-making was formally viewed as a fairly linear operation, with the line going from a department to the principal, or from the principal to a department. Fortunately, we had principals at Orange Grove in my first 11 years there who regularly chose to include some or all staff members in decisions, but there were no structures in place to expedite the consistent inclusion of all staff members, let alone students and/or community members, in formative and/or summative decision-making stages. Although Orange Grove was a "successful school," i.e., one in which our students consistently performed well academically and athletically in comparison to other schools in Southern Arizona, we had not come to perceive ourselves as a "...whole whose elements 'hang together' because they continually affect each other over time and operate toward a common purpose." (Senge et al, 1994, 90)

Once we began the transition to being a middle school, we deliberately built in what I now recognize as Deming's ninth principle of breaking down barriers between staff areas. We did this physically as well as organizationally. Physically, we remodeled existing classroom pods so that each pod housed five classrooms and one common work area for the staff who would be working in that area. Previously, each pod had housed six classrooms, with no common area in the building for staff members. In fact, the only common staff area in the school was a small lunch room. Eventually each pod housed teachers who had job-alike assignments–teaching the same subject and/or the same grade-level students.

Communication among teachers teaching the same grade-level students became a focal point of our organizational structure, as it had of our physical structure. A common element of middle schools is that teachers and students form "teams." At Orange Grove we created grade level teams. One implication of that for the staff was that we built into our schedule a common plan time for all the teachers who taught the same grade level, allowing time for interdisciplinary planning that hadn't been built into the schedule previously. Now the team of seventh grade teachers, for instance, could meet together during the week to discuss curriculum they were presenting to the seventh graders in various classes, to discuss any concerns anyone had about a student, and to take care of "business matters" such as ordering of supplies, or making changes to the seventh graders' schedule for special events. What this scheduling of common plan time did was highlight interrelationships among teachers who shared experience with a common group of students, thereby focusing attention on experiences students were having throughout a day or week, not just throughout their years as a math or social studies student, as had been the case when most communication was done within departments.

In addition to grade level teams, we also created a "support" team and an "arts and foreign language" team, both teams being comprised of staff members who work with students "at large," i.e., not with students in a particular grade level. This meant that each staff member, whether s/he were the principal, custodian, health room assistant, art teacher, secretary, Spanish teacher, or librarian, was a member of a team that would meet regularly to discuss the work they were doing in the school and how their work related to the work of other teams.

Our growing understanding of systems thinking led us to study not only what structures we wanted to create in order for us to deliver the cohesive program we wanted to present to students through teams, but also challenged us to make, as Richmond says, "...reliable inferences about behavior by developing an increasingly deep understanding of underlying structure." (Richmond, 1994) One of the inferences

we made about behavior at Orange Grove was that creating physical and scheduling structures that allowed us to work more systemically within teams did not necessarily give us the structures necessary for dealing with the feedback we wanted between teams, feedback that would inevitably come whether we were ready for it or not. We wouldn't be working intelligently as a system of interrelated parts if we didn't build in structures to accommodate interteam communication.

We've handled this communication challenge at Orange Grove by establishing "task teams" which are comprised of a member from each of the grade level, support and arts/foreign languages teams. Throughout the years, the tasks for which these teams were responsible have changed, based on our assessment as a staff of what the needs were within our system. (Some of the current task teams are Instruction and Assessment, School Environment and Culture, Student Welfare, and Technology.)

I mentioned in the previous paragraph that teams were "responsible" for certain tasks. The "responsibility" issue is one that I think has evolved over time at Orange Grove as we have learned more and more about systems thinking and system dynamics. Not only have we built structures at OG that facilitate communication, but by also giving teams the power and responsibility to make various decisions for themselves, rather than leaving those decisions for an administrator to make, we have integrated systems thinking with Deming's principles of quality. As staff members have more responsibility for the decisions made within the school, we come closer to achieving two more of Deming's principles of quality–the principles of driving out fear and removing barriers that rob people of pride of workmanship.

Each team now controls its own supply and travel budget, for instance, rather than having it controlled by the principal. This means that when team members meet during their common plan time or during a task team meeting, co-workers decide what can and should be purchased, or who can and should travel to a particular conference. As you might imagine, making such decisions is not always easy, but to truly understand how each person's actions, e.g., purchasing or traveling, affect one another within the system, the people within the system need to make those decisions, rather than having them made by an administrator who is one step removed from the team.

Likewise, for people to have pride in their work, they need to be doing meaningful work, which each team at OG does. For example, just last week the School Environment and Culture task team organized "shared vision lunches" for the staff during all three of the school's lunch periods. Task team members planned the pot luck lunches and facilitated discussion during the lunch time in order to follow up on input the staff had generated at a December meeting regarding key components of our system that need attention in the second half of the year. Although the principal had led the December meeting, a task team of which she is not a member took over the coordination of continuing the important December discussion. Such roles of coordination and facilitation were once left to the administrators and to a few chosen staff members, but now every task team member–every staff member–recognizes that s/he is an essential component of the OG system and works to share the responsibilities of creating and maintaining a fine school program.

If a team begins to feel that they aren't contributing meaningfully to the entire system, as in the past some task teams have felt, or if a team feels that they aren't connected as they'd like to be with the work of another team, the structures are investigated to see if we need to make adjustments within a team, among various teams, and/or within one of our underlying communication or decision-making structures. Once again, staff members within their teams, including administrators within the support team and task teams they're on, decide what issues to pursue and what structures to pursue them through. I believe this increased participation in decisions, and the responsibility that goes with it, helps each staff member understand the interrelationships within our OG system and helps us achieve a number of Deming's principles of quality.

CONCLUSION

Although not having set out to do so, I believe that in a good deal of our work within the classroom and the organization at Orange Grove we have integrated key components of Deming's quality principles and his thoughts on systems as a component of profound knowledge, with key elements of system dynamics and systems thinking. We want the OG students, staff and community to understand the systems in which they operate so they can make informed decisions throughout their lives, and we hope that we will all be part of systems that are doing quality work. I believe by integrating quality principles with SD and ST, we are attempting to do what I heard Daniel Kim, speaking at a systems in education conference in Tucson, attribute to Gandhi–"Be the change you want to see in the world." (Kim, 1993) By making the changes we have at Orange Grove, and by staying open to "seeing processes of change rather than snapshots," (Senge, 1990, 73) we are becoming the type of quality system we want to see in the world. We at OG recognize that we have just begun to see the benefits for students, staff and community that this integration of quality, SD and ST can produce, and we look forward to the challenges and opportunities we will discover as we continue this work.

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BIOGRAPHICAL SKETCH

Joan Yates is in her second year as the System Dynamics Project Manager in the Catalina Foothills School District in Tucson, Arizona. She has eight years experience teaching junior high school English and mathematics, three years experience as a junior high school administrator, and three years experience teaching writing and literature at Orange Grove Middle School. Both as a member of the Orange Grove staff and more recently as the System Dynamics Project Manager, Joan has collaborated with fellow staff members to implement concepts of systems thinking, system dynamics, and the learning organization within individual classrooms, the school, and the district.

Joan received her B.A. in English from the University of California, Davis.