Lessons for System Dynamics Mentors in Schools

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abstract

The successful, large-scale introduction of system dynamics into education requires many supporting elements. One important element is an institutional structure that supports school change. A major part of such a structure needs to be the availability of expert system dynamics mentors to provide on-going training and support for teachers.

This support occurs on three tracks. One track is relatively formal—workshops and meetings spent cooperatively developing projects. Another track is classroom observation and documentation. The third track consists of encounters "by the coffee machine", and consists of informal, brief conversations where the mentor and teachers can brainstorm ideas or confer on a current project. These methods of on-going support are preferable to the more conventional format of short-term intense workshops, which research shows has little long-term effectiveness.

In this paper, the author discusses his experience as part of the System Dynamics Project in the Catalina Foothills School District (CFSD), located in Tucson, Arizona. Specifically, the author has been a system dynamics mentor at Catalina Foothills High School (CFHS), since the Fall of 1992. As a mentor, the author works with teachers and administrators facilitating the use of system dynamics as a method of instruction.

Lessons for System Dynamics Mentors in Schools

Introduction

In the Fall of 1992, I began work as a "System Dynamics Mentor" at the newly opened Catalina Foothills High School (CFHS), part of Catalina Foothills School District (CFSD) located in Tucson, Arizona. In this article, I'll try to summarize my role as well as describe some lessons I've learned while facilitating system dynamics in a public high school.

The Birth of a School

Being part of a new school is an interesting, if somewhat chaotic, experience. New grades are being added at a rate of one each year (ninth grade in the Fall of 1992, tenth grade in the Fall of 1993, etc.). An advantage of this progression is that teachers have a chance to develop one year of curriculum at a time. This is a great opportunity for those teachers interested in system dynamics, for in consultation with me they can cooperatively design lessons and activities utilizing the tools of system dynamics to help implement their curriculum.

The System Dynamics Project

The System Dynamics Project, part of the district-wide, privately-funded Waters Grant, is intended to "use the tools of system dynamics in classrooms to continuously develop the ability of students and teachers to understand complex, dynamic situations" ("Waters Grant Proposal" 1993). To work toward this goal, four full-time mentors are currently employed throughout the district: I am at the high school, one mentor is at each of the two middle schools, and one "mentor-in-training" is beginning to work with all three elementary schools.

Mentor Roles

When I was hired my job description read (in part) that I should "Develop well-documented STELLA models... Assist in staff training in systems thinking and system dynamics." However, the description gave little hint as to how to do so on a day-to day or month-to-month basis.

Now that I have two years of mentoring experience, I see a mentor as playing several interrelated roles (please note that the role of a system dynamics mentor is still evolving, and any description of such a role is necessarily a subjective "snapshot"):

1. Working with teachers on brainstorming, designing, and implementing lessons that use system dynamics tools and activities.
2. Doing programming and model-building as needed to implement these activities.
3. Documenting models and system dynamics activities.
4. Training teachers to use and build system dynamics models.
5. Serving as a consultant to students as they work on school projects that utilize system dynamics.
6. Encouraging inter-teacher communication on systems issues.
7. Maintaining ties to the system dynamics community.

Note that I don't design curriculum. While I am the expert in regard to system dynamics, each teacher is the expert in regard to their subject area. Ideally, when a

course includes a topic that has a strong dynamic component, the teacher will work with me to include system dynamics activities to help teach it. I see system dynamics primarily as a method of instruction rather than as a unit of curricula to be taught by itself. This focus on system dynamics as a means rather than an end doesn't preclude teachers' expanding their curriculum to include more dynamic elements after being exposed to system dynamics.

Example Project

In the spring of 1993, the Human Biology teachers taught a unit on anatomy and physiology, structured as follows: At the beginning of the unit, students received a "client" with specific health problems or conditions. Over the next eight weeks students had to design a realistic, healthful fitness/diet/lifestyle plan for the client. All the physiological information they learned during this unit was needed for this final event. Because the teachers saw a need for system dynamics, they sought me out and invited me to become involved in planning the activities for this unit.

The teachers met with me to study system dynamics a number of times in late winter, both after-school and in a day-long workshop. I then worked with a retired Tucson cardiologist doing research on exercise and its effect on the body. By late February the two of us had created a packet of notes for teachers complete with activity suggestions, causal loop diagrams, and STELLA diagrams. Simultaneously, I programmed a STELLAstack simulation on the effect of exercise on oxygen flow. From the Creative Learning Exchange I also acquired a STELLA model and worksheet covering blood sugar regulation. I worked with all of the teachers on an individual basis to make sure that these materials fit their needs and to train the teachers in their use. Finally, we were ready to start.

In early March, I taught each science class and led a workshop on using causal loops to analyze respiration. I did this to model for the teachers how to use causal loops in the classroom. Some of the teachers followed up in later classes with their own loops or modifications of mine. Since students were required to do two causal loop diagrams as part of their reports, I also met with many students giving one-on-one advice during my daily "office hours". In addition I assisted the teachers the first time they ran each activity I had helped design. During STELLA exercises I was in the classroom even more frequently.

I am not so completely involved with every project. Since this was the first science unit to heavily incorporate system dynamics, I needed to work closely with the teachers. It is also important to note that I did not dictate what teachers did in the classroom. Instead, I provided different resources including examples of activities that they could modify to fit their needs. In later projects with these teachers I have taken more of a supporting role and did less actual activity design.

Lessons for Mentors

Lesson 1: How to get teachers interested in system dynamics: Drink lots of coffee.
Any new educational innovation must compete for the school's most valuable resource: teacher time. It can be hard to fight the implied catch-22 situation. Often, teachers need to spend time learning about system dynamics and its application to their subject in order to want to allocate that valuable time to learn more about how they can implement system dynamics in their classroom.

My major strategy is to talk about system dynamics all the time. The best place to

plant a seed of interest is not in a formal meeting, but as part of a random interaction instead: for example, by the coffee machine. When I have a project going with a teacher, I tell other teachers about it, describe the interactions of kids to teachers, even invite people into the classroom to observe. By doing this I encourage teachers to see possible uses for system dynamics and related instructional techniques.

Lesson 2: Start with the teacher's current curriculum and go from there. Don't try to convert teachers to the "religion" of system dynamics.
When I begin working with a teacher I usually begin by asking questions. Why is the teacher teaching this topic? What are the assumptions the teacher uses in designing his/her instruction? What are the elements of the current curriculum that can be quantified and that are dynamic in nature? What types of causality are significant in this content? How do people use in the real world the knowledge their students are currently learning? I also try and find out the teachers doing that is similar to projects being done by teachers who already use system dynamics. I then can start determining the system dynamics applications that are likely to "hook" this particular educator.

The question, "What are you already teaching that system dynamics can help you teach better?" can often provide a "foot in the door" to start a project with a teacher. For example, behavior–over–time graphs are a good first tool, because they are easy to learn and can generate quick insights into almost any situation. For example, I might work with a social studies teacher to graph the political tension inside a country for the decade before a revolution. Or encourage an English teacher to graph changes in a character trait over the course of a story. In either case, the point is not to draw "the right graph," but to engage in discussions of underlying assumptions of meaning and causality. (This tool can be particularly effective when people have differing interpretations of the dynamics of a given situation). Depending on the teacher's familiarity with system dynamics I may also bring in causal loops, stock/flow diagrams or a STELLA model. The important thing is to discuss what kinds of uses the teacher might find for system dynamics while dealing with existing content.

Lesson 3: Teachers' mental models have a large influence on their interest in and ability to use system dynamics.
In 1988 Dr. Gordon Brown, retired Dean of Engineering of the Massachusetts Institute of Technology, introduced Frank Draper, then a seventh grade science teacher at Orange Grove Middle School, to system dynamics. In a story that is legendary in CFSD, Dr. Brown lent him a copy of STELLA and a Macintosh computer for the weekend. "Draper returned with the comment, 'This is what I have always been looking for, I just did not know what it might be.'" Frank Draper's mental models regarding science education enabled him to quickly implement system dynamics in his middle school science class, and later to start working with other teachers, becoming the first system dynamics mentor in our district (Forrester 1991).

On the other hand, some teachers have mental models that hinder them from applying system dynamics. Teachers who see their content as a set of discrete, event-driven topics or rules have particular difficulty in seeing uses for system dynamics. For example, many teachers of mathematics view math as "a rigid system of externally dictated rules governed by standards of accuracy, speed, and memorization" (Battista 1994). This discrete perspective (reinforced by the fact that most math teachers learned their subject in this manner), conflicts with a number of

the assumptions behind system dynamics. Specifically this view is incompatible with system dynamics' emphasis on the modeling process rather than a "final model" (Forrester 1985), and the important modeling step of "what-if?" sensitivity and policy analysis (Sterman 1988). The mentors' experience in CFSD also shows that system dynamics models appear to be most effective when used to model a specific situation, rather than, for example, an abstract computational rule (Draper 1990).

Lesson 4: Teacher release time is an important, but not sufficient, condition for educational innovation.

Teachers need time to brainstorm ideas, learn skills, and to develop and evaluate lessons. Teaching is generally a time-consuming, professionally-isolated career; in most schools there are few opportunities for collaboration, reflection, or professional growth during the academic year (Corcoran 1990). Before teachers can start using system dynamics in their classroom they need release time that will allow them take part in these activities. In order to accommodate this need, the System Dynamics Project hires substitutes to replace teachers periodically throughout the year. Teachers have used these days for (mandated) group introductory system dynamics workshops and for meeting with a mentor to observe, plan, or document a system dynamics activity.

There are some obstacles in using release days with teachers. Taking a day out of the classroom requires that the teacher make a special lesson plan and trust the substitute teacher to carry it out effectively. Teachers who do not have a specific idea for a project may find it hard to justify the necessity of a "systems day."

Finally, it is unclear how effective the mandated introductory workshops are for teachers. On the positive side, these workshops expose all teachers to a set of tools that are being used by their students in classes throughout the school. By grouping participants by discipline, I can design each workshop to focus on examples and approaches relevant to those teachers. The workshop can also be a good opportunity for teachers to discuss professional ideas and techniques with their colleagues in a setting removed from the urgent demands of a typical school day. On the negative side, planning and running these workshops are time–consuming for the mentor, especially when not all teachers may be interested in pursuing the use of system dynamics after the workshop. Despite these difficulties, it seems that these introductory workshops are an important way of promoting initial teacher-mentor interaction.

Lesson 5: School culture has a major influence on educational innovations.

A school is an organization composed of teachers, support staff, administrators, and others. Each group works under different conditions with different perspectives and beliefs about the operation of the school. Together, these conditions, perspectives, and beliefs form the school culture.

The mentors at CFSD have found that differences in culture between different schools can have a significant impact on the introduction of system dynamics.

Some of these varying conditions in a school that can affect an educational innovation are:

- willingness of teachers to collaborate
- opportunities for informal interaction between teachers
- desire of administrators to maintain the status quo
- student respect for property and equipment

and most importantly:

- Trust between teacher and mentor, between teacher and student, between teacher and administrator, and between teacher and the community.

As applications of system dynamics increases throughout Catalina Foothills School District, it will be important to remember that causality is usually circular. It remains to be seen whether as the district fosters the use of system dynamics in classes, whether that use will feed back and cause changes in the overall organizational culture of the schools in the district.

Lesson 6: Don't shift the burden to the mentor.
Research shows that skill-specific training (e.g. short-term intense workshops) is often a poor method of promoting school change. Initially, this type of training has strong, positive effects on the teachers and students involved. "But, when the experts leave, teachers discontinued using the practices that had apparently enhanced student performance because they had never really learned them in the first place" (McLaughlin 1979).

Once the mentor is familiar with a teacher's curriculum, the temptation is strong for the mentor to use his/her expertise to design models and causal loops without involving the teacher. In those cases, the teacher may then have a well-designed set of system dynamics activities, but the mentor might have prevented the teacher from learning the skills necessary to develop future system dynamics activities without that expert assistance.

Instead of "doing the work for the teacher", informal support may be the solution, both of the coffee machine and classroom variety. Teachers often desire feedback about the effectiveness of their instructional practices. Being an expert "sounding-board" for ideas and techniques related to system dynamics that the teacher is using may ultimately help a teacher more than having their activities designed for them.

Lesson 7: Encourage educators to make connections between different ideas or situations.
One of the more powerful ideas in system dynamics is the existence of generic structures: similar patterns of relationships that cause similar patterns of behavior. Teachers often tend to focus on individual systems (i.e. what they are teaching at the moment), and may need some support in recognizing and applying connections between seemingly different topics.

The kind of support I give to a teacher varies depending on the situation and the teacher's experience. I help the teachers to make connections between different disciplines by talking about what I've observed different people teaching in their classes. I may help a teacher find readings or other resources giving different points of view on a particular topic. I ask, "What are the causes of that event? What are some of the general principles involved?" When it is appropriate I push the teacher to search for feedback or a system archetype.

Lesson 8: Research is needed on many issues concerning the appropriate role of system dynamics in K–12 education.
System dynamics is still an educational discipline in its infancy; many issues lie unresolved. For example, an unresolved theoretical issue concerns the manner in which system dynamics affects student cognition of academic content (Draper,

"Student Systems Models" 1993). A significant implementation question asks which classroom structures work most effectively with system dynamics. (Classroom structures referred to include grouping arrangements, type of tasks students are performing, and methods of assessment.) An issue of both theoretical and practical value concerns what is the most appropriate sequence of activities for developing systemic thinking in elementary, middle, and high school students (Draper, "Proposed Sequence" 1993). The System Dynamics Project is currently funding a part-time researcher to study the first of these issues over the next few years.

Lesson 9: Use system dynamics to help spread system dynamics.
A school is a classic complex, dynamic system. It is filled with a number of different interest groups, each with its own agenda. Educational trends cycle back and forth. The most significant factors in a school system may not be the tangible, easily measured quantities we usually pay attention to such as the number of pupils or amount of money in a school system, but may be the more subtle quantities of attitudes, experience, and memory. Change is an incremental process, often taking many years.

Experienced system dynamicists need to spend time in a school environment and use system dynamics in collaboration with teachers and administrators to study how change occurs in a school system. A current project of the System Dynamics Project is to build a model of its mentoring program; by doing this we hope to determine the most effective leverage points to help us foster the continued use of system dynamics in the Catalina Foothills School District.

Lesson 10: Keep learning how, but always remember why.
The field of system dynamics has many dimensions. One is as a set of tools for analyzing feedback causality and change over time. These tools include behavior-over-time graphs, causal loops, stock/flow diagrams, and STELLA models. I call this the "How" of system dynamics. A second dimension is somewhat more ambiguous. This perspective, which I sometimes refer to as the "Why" of system dynamics, involves a pantheon of ideas about how the world works and how to study it in a systemic manner.

It is easy to get involved in the "How" dimension of implementing system dynamics tools and to skip past the philosophical reasons that the "Why" dimension provides. This is dangerous ground, because the blind use of system dynamics tools can be just as pointless as the inappropriate application of any educational technique.

It is also easy to get so involved in the philosophy of system dynamics– the "Why?"– that you never get around to using any of the tools. Those who exemplify this perspective proclaim that "everything is connected to everything." but never actually analyze any situation with a system dynamics tool. The danger here is that people who follow this approach are often the most visible proponents of system dynamics. By saying much about system dynamics but doing little with it, these people reduce the credibility of the field of system dynamics as a whole.

We need to help students discover that the world is a complex, dynamic environment. It is filled with situations where conditions cause actions which come around and affect those conditions. Cause is often far removed from effect in both time and space. Short-term and long-term effects of policies are often quite different. Solving the symptoms of a problem rarely solves the underlying

problem. These are some of the philosophical precepts that are fundamental to the field.

System dynamics is a powerful educational methodology when both the "How" and the "Why" dimensions are taken into account. Any application of system dynamics should be able to be justified according to the curriculum and the issues above. Mentors and teachers using system dynamics should continually investigate these general system dynamics issues along with creating specific applications for their classrooms.

When our current students become adults and enter the twenty-first century, they will find the world to be even more complex than it is currently. Teaching them the tools of system dynamics and the knowledge of how and when to use them should help to make their world— and ours— a better place in which to live.

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