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Effective Use of Simulations in the Classroom

by Jane Chilcott, Catalina Foothills School District System Dynamics Project

This paper is the product of my early retirement program in Catalina Foothills School District. When I decided to retire after twenty-five years teaching middle school in the district, I met with the superintendent, David Ackerman, to discuss ideas for a project to fulfill my commitment of forty days work. He expressed the hope that I could do something to insure that my expertise in using classroom simulations could be captured in a form that would help future teachers continue the effective use of this teaching method. The ensuing partnership with the System Dynamics Project made this paper possible and probable. And as a result of this collaboration we were able to include computer assisted system dynamics simulations in the guide.

When I first encountered simulations as a teaching tool, they were called simulation games and as such had score-keeping, winners and losers. In those days competition in the classroom was not only tolerated but fostered; it was assumed that competition was the key ingredient to student enthusiasm for this teaching method. Typically an assignment would be made that involved learning certain material (objectives) in order to play the game. In fact, the student who successfully completed the assignment first not only earned the most points but was allowed to choose his part in the simulation game. This had the double purpose of being an incentive to students and assuring the teacher that the "smartest kids" would get the best parts. As the best parts usually held the probability of earning the most participation points, those students would continue to receive the highest grades. This appeared to be fair because it perpetuated the accepted system and insured that the learning activity ran smoothly because the most capable students were in charge.

After suffering through some devastating problems involving game scores and student grades as well as struggles with my conscience about fairness, I finally realized that the simulation could stand on its own without the game aspect, without a winner and the consequent losers. Every student could accomplish the objectives and, indeed, was expected to do so; collaboration could replace competition and good grades rewarded good learning and were not rationed. Hidden talents emerged as unlikely students excelled in starring roles and the simulations got better and better. This legitimized classroom simulations as a philosophically sound teaching method. Students played on a level field with many options available to accommodate individual differences. The simulations continued to be highly motivating and fun for an even higher percentage of students.

Toward the end of my career I found it difficult to teach without using a simulation although I occasionally

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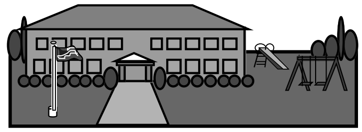
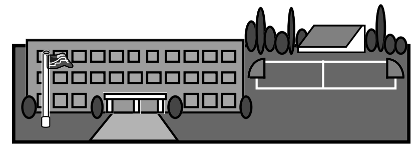
Build New Schools or Wait? A school construction decision making simulation

by Matt Hiefield





While growing up in Portland Oregon, I noticed that some of our city schools were closing and others were being converted to middle schools or were bought by businesses. Changes in the population (and possibly some faulty planning decisions) led to this dilemma. As schools closed and consolidated, much anger was vented by parents and students.

Currently, however, I find myself in a district with the opposite predicament. Beaverton School District, located in a Portland suburb and home of Nike and

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Updates. . .

St. Louis, Missouri

This note from Art Schneiderheinze came to us through the K-12 list (see box for sign-up information). I have included it here as well as the reply from George Richardson. We will have a follow-up in the next newsletter with the models the students are creating and their insights from the models.

I am doing a unit on theme park dynamics using Stella to model systems inside the park—such as the flow of people in and out of gift shops, game booths, etc.

We are currently in the process of analyzing the systems (rides, game booths, restaurants, shows, and gift shops) to determine what elements are variable and constant. Knowing this will assist them in determining what elements (as a park designer) they have control over.

We also surveyed over 1000 people at Six Flags to gather data to support the decisions they make for their final projects—innovative parks for the year 2015—which solves the flow problems we see in parks today. booths, rides, restaurants, and shows.

The kids (5th grade gifted) did really well setting up the models, collecting data at Six Flags, and writing the equations (with some help from me).

Question: Any ideas of how we can use these models now to redesign each system to make it more efficient? For example, one group experimented with two elements in their system (rides)—first, the number of seats in each car, and second, the length of the ride cycle.

They concluded that the number of seats impacts the length of each queue the most. They figured that they should redesign the system by designing a coaster that has more seats per car.

It seemed difficult to get the kids to do the experiments. I challenged them to choose two constant elements in the system and change each one, one at a time. They looked at how the flow of people changes: did the number of people waiting in each queue change? did the amount of time waiting in line change? did the number of people exiting each hour change?

It was really hard for them to support their conclusions about which element affected it the most. Anyone have any ideas of how to help facilitate this better?

Art Schneiderheinze, Gifted Education Teacher 5th grade Center for Creative Learning, *cct18@mail.rockwood.k12.mo.us*

On redesigning the system to work better:

The kids would probably have to enlarge their system boundary to get good answers on system redesign. For example, if one put more seats in the cars (or more cars per ride), then waiting lines might initially be shorter, but that would attract more people to this ride, and waiting lines would get long again. Presumably waiting lines are the result of the overall relative attractiveness of the ride, relative to the others in the park, and waiting lines are part of that relative attractiveness.

If the kids redesign the system to have more cars but don't have the relative attractiveness idea in there, or the notion that people attracted to the ride per unit time is a variable, then they would miss this compensating effect.

In the long run what we're after is habits of thought that seek out and identify effects that will tend to compensate for policy initiatives. I'm not sure how one would work with the kids on this modeling project to get them to this sort of thought process, but it's the goal nonetheless.

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From the Editor . . .

As we head into winter in the Northeast, it is wonderful to think of the students across the country who have the opportunity to learn the concepts of system dynamics and systems thinking—many more than when we started the CLE 5 years ago.

As you can see from our articles and updates, teachers and administrators are using the tools of system dynamics and systems thinking in their classes and in their administrative work. It is terrific to hear about 5th graders in St. Louis modeling. Hearing what others are doing stretches our imagination and the horizons of what we think can be done with students. Do you have a story about your students? I would love to share it in the newsletter.

Look at our new materials list on page 11. We have quite a number of interesting new articles and curricula available. As always, these are available to download from the Web (*http://sysdyn.mit.edu/*) or at cost from us. I think you will be delighted with the new materials.

Have a productive end of the fall and beginning of the new year. May your winter break be refreshing to you and your students.

***Lees Stuntz** (stuntzln@tiac.net)*

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did for a breather and to provide the students with a basis for comparing teaching methods. When Frank Draper introduced computer assisted system dynamics simulations in his science classes, we became interested in the possibility of designing simulations for social studies and science together. This paper, by discussing and comparing two types of simulations, may foster that development in the future.

Introduction

In Catalina Foothills School District simulations have been used successfully for many years to teach social studies content in a real world context: a mock trial can be used to teach students about the court system; a mock Congress provides a forum for learning how laws are made. A model United Nations helps students understand the difficulties of seeking world peace. More recently, highly motivating and innovative computer-assisted simulations were developed to enhance learning in the science curriculum. A mining simulation teaches not only geology but decision-making that takes into account environmental issues. Designing a Park Project parallels real world problems between protecting the environment and providing for growth. In both types of simulations students increase their understanding of how a real world system functions and become aware of how that system connects to other real life systems.

Classroom simulations motivate students by keeping them actively engaged in the learning process through requiring that problem solving and decision making skills be used to make the **simulation** run. As the simulation runs, it is modeling a **dynamic system** in which the learner is involved (plays a role).

Thus participation in simulations enables students to engage in **systems thinking** and enhances their understanding of systems as well as of social science and/or science concepts.

This paper provides information that will help teachers understand *what a simulation is* as well as *when and why to use one.* Two types of simulations, *system dynamics simulations* and *role -playing simulations* will be explained and related to each other. Detailed information will be provided to help teachers implement simulations in their classrooms. This includes: what to do *before the simulation,* scripts for *setting the stage* with students, a *definition of debriefing* , its impact on learning and examples of *debriefing questions.* The *Appendix* includes a *glossary,* a selected list of *simulations being used* in CFSD, an overview of the process for *designing* system dynamics and role-playing simulations, *sample documents* and a list of *resources***.**

What is a Simulation?

A classroom simulation is a method of teaching/learning or evaluating learning of curricular content that is based on an actual situation.The simulation, designed to replicate a real-life situation as closely as desired, has students assume roles as they analyze data, make decisions and solve the problems inherent in the situation. As the simulation proceeds, students respond to the changes within the situation by studying the consequences of their decisions and subsequent actions and predicting future problems/solutions. During the simulation students perform tasks that enable them to learn or have their learning evaluated.

A simulation includes time for reflection and processing which allows students to share their experiences, assess their learning and evaluate their assessments against the intended outcomes of the simulation. In addition to accomplishing the objectives of the simulation activity, students often become interested in the real world system on which it is based and what makes it work the way it does.

A simulation is an instructional strategy (teaching method) that can be used with appropriate learning material at any level from the primary grades through graduate studies. The complexity of a simulation should reflect the grade level and the sophistication of the material being taught or evaluated. There are published simulations available for purchase but many teachers prefer to create their own. A well-designed simulation simplifies a real world system while heightening awareness of the complexity of that system. Students can participate in the simplified system and learn how the real system operates without spending the days, weeks, or years it would take to undergo this experience in the real world.

Periodic discussions provide the opportunity for students to collect their individual experiences, discuss the general principles or ideas contained in the simulation and relate these ideas to the real world situation. It is important for teachers who use simulations to allow time during the simulation for this discussion. It is also important to have "debriefing" discussions during and after the simulation. The debriefing, which should be as well-planned as any lesson, provides closure for the activity and should focus on the learning outcomes for the simulation. Some suggestions on how to lead post-simulation discussion are provided in the *Introduction to Debriefing* section.

For purposes of clarity it is necessary to distinguish between "role-playing" and simulations. When role-playing, students act out a predetermined set of events with foreknowledge of the outcome of their characters' actions. The purpose is to acquaint them with the historical scenario and to develop an awareness of the factors influencing a decision made at that time. It also allows students to practice "walking in someone else's shoes" and can lead to meaningful discussions about events that occurred in the past. An example would be role-playing the decision to use the atomic bomb in World War II.

In a simulation, students' actions determine the outcome of the situation they are simulating. The situation being simulated has existed, exists or could exist in the real world but the simulation modifies it to fit the param-

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eters of classroom teaching. Passing laws in a mock Congress is an example of a simulation.

Deciding to Use a Simulation

Using a simulation as a teaching/evaluating method can be considered whenever the curricular material can be learned or student learning of prerequisite material can be evaluated, through their participation in a mock real world situation in which their choice of actions determines the outcome of the situation.

Teaching through a simulation requires a time commitment and carefully orchestrated organizational scheme from the teacher. The role of the teacher includes designing or adapting the simulation to fit the unique needs of a group of students, teaching content/skills necessary to participate in the simulation, observing student interactions, monitoring and adjusting the simulation as necessary, assessing student learning, evaluating the simulation as a learning experience, and presenting the learning activity with great excitement and enthusiasm. Materials must be created and copied; each day's activities should be scheduled. In addition the teacher needs to allow time throughout the simulation for discussion. Because the teacher must do much of the work prior to the simulation being run, teacher time during the simulation is available for observation and coaching which are excellent ways to assess student learning. Using a classroom simulation is a lot of work but the success of students in a well-designed, appropriate simulation is extremely rewarding for students and teachers.

The authentic nature of many simulations can be highly motivating. The teacher's enthusiasm can be contagious especially if the role-playing is presented to students as a wonderful opportunity to change their identities. Students are actively engaged in the learning process as they solve problems and make decisions as this is done in the adult world. Simulations provide a forum in which creative, divergent thinking is legitimized and valued. Because simulations are much more like the "real world" than many classroom methods, students do not stop learning when the class period is over. Their interest carries over into informal out-of-class discussions with other students and adults in which experiences and ideas are shared and evaluated. Enthusiasm bubbles and school attendance is high. Students become educational ambassadors as they continue their discussions at home. Students describe this kind of learning as authentic and not boring.

When simulations are used for assessment or evaluation of prior learning of the content necessary to successfully participate in the simulation, some students may not be successful due to deficiencies in their grasp of the prerequisite material. If the opportunities and encouragement are provided to go back and learn the material and try the simulation again, every student could eventually be successful. Other students will volunteer to assist in these extra simulations held after school or at lunch because it is fun.

After considering these factors, if you think your teaching/learning objectives can be accomplished through a classroom simulation, the following sections of this paper will examine types of simulations and offer assistance in their implementation in the classroom.

Types of Simulations

This paper distinguishes between two types of simulations, role-playing and system dynamics simulations. While both meet our definition of classroom simulations (p. 1), the difference is a matter of focus and the emphasis on using computer technology.

Role-playing simulations provide students an opportunity to learn through playing a role in a scaled-down real-life situation in which students assume real world roles as they solve problems and make decisions. The student can see and discuss the results of these actions within the parameters of the simulated situation. In terms of application to the real world, he can hypothesize the impact of his actions but cannot ever know the consequences that course of action would produce in the real world. Through his participation, however, the student learns how the real world system operates and experiences the trade-offs involved in decision-making within that system.

The focus in a role-playing simulation is on "learning by doing"– students learning how decisions made and actions taken within the system they are simulating lead to both short term and long term consequences within that system. Although most of the curricular content will be learned throughout the simulation (including debriefing), some prerequisite learning about roles within the system may need to take place before the simulation begins. The appeal of this methodology lies in the student being able to assume the identity of the role he is playing and discard his school identity. This frees him from the limits to learning that may be inherent in his reputation. Tremendous excitement is generated by this transformation which is contagious among students running the simulation and within the school community.

Computers, while not essential, can be helpful tools for teachers and students as they participate in a role-playing simulation. The computers can be used to store and retrieve information, present information in multiple medias, and provide additional structure to the activity. Computers facilitate bookkeeping, speed up research and accelerate and compress time.

Because they are an effective and fun learning strategy, role-playing simulations are an educational technique that has been used successfully for many years. They can be purchased from a number of sources for teaching/evaluating a wide range of learning objectives. Teachers often adapt these to meet the unique needs of their class and curriculum; other teachers create original simulations. See *Appendix* for simulations suggested as instructional strategies in CFSD's social studies and science curricula.

System dynamics simulations are designed to help students experience a real-life situation as it plays out over time. The simulation is based upon a mathematical model of interrelated quantities that numerically describe the situation. Because the simulation is entirely based on elements that can be quantified as numbers, typically system dynamics simulations have a narrower scope than role-playing simulations. The actual enactment of a role in a system dynamics simulation is usually not as important as it is in role-playing simulations (although it can be made an integral part of the simulation).

A computer is an important part of a system dynamics simulation because it stores the underlying model holding information about the simulated situation. The model enables the computer to simulate, a step at a time, the real-world situation, based in part upon the student decisions. During each round of the simulation, the students make decisions and input these decisions into the computer. The computer uses the model to calculate new values for the other elements in the system. It then displays them to the student as numbers or graphs. Students make new decisions based upon this information, and the process repeats again.

Most of the work in preparing a system dynamics simulation is involved in building an appropriate computer model. Teachers can create their own system dynamics models independently, in collaboration with a **system dynamics mentor**, or use a model from one of the sources listed in the Appendix.

Use of System Dynamics Tools with Simulations

System dynamics is the study of systems and how they change over time. A system is defined as "a collection of parts which interact with each other to function as a whole." (Kaufman, Jr. p. 1) For example, an automobile is a system; a central heating system is another. "Systems can contain people as well as physical parts." (Forrester 1968) A person driving an automobile (steering the car as the road twists and turns) is a good example of this. Other examples of systems containing people are governments, economies, revolutions, and wars.

System dynamicists assert that cause and effect usually happen in a circle, called a **feedback loop.** A condition provides the basis for an action which changes the condition which causes a change in the next action. For example, if the temperature in a house is too cold the thermostat will turn on the furnace. The furnace raises the temperature until eventually the furnace shuts off. This self-regulating system is an example of a "balancing loop".

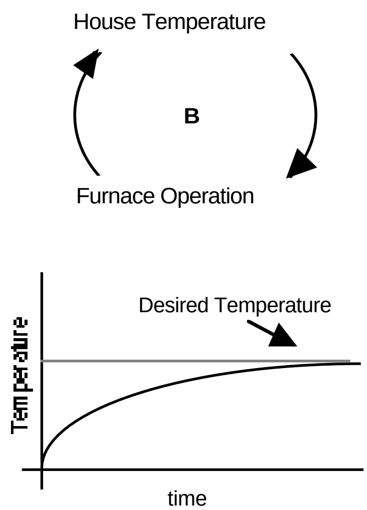
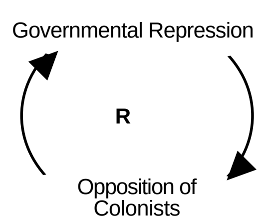


Figure 1: House Temperature

Another example: one theory of why the American Revolution began is that the colonists opposed the ruling British government because they felt oppressed. In response to the colonists' actions the government tried even harder to repress its rebellious citizens. This caused the opposition of the colonists to escalate, leading to war. This self-reinforcing growth pattern is typical of a "reinforcing loop".



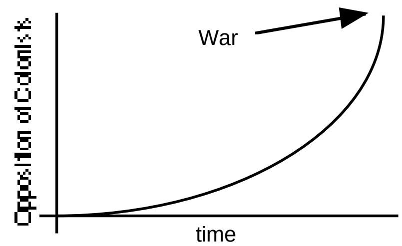


Figure 2: Revolutionary War

System dynamics provides six tools to help study systems and their behavior. One of these tools is the system dynamics simulation discussed in the previous section.

Two more tools, a **causal loop diagram** and **behavior-over-time-graph** are shown in Figures 1 and 2. Other system dynamics tools (all tools are defined in the glossary) are:

• **system archetypes**
• **stock-flow diagram**
• **system dynamics computer models** created with software such as STELLA II

Teaching students to use these tools appropriately enables them to become involved in systems thinking: conceptualizing, synthesizing and analyzing dynamic systems. More specifically, systems tools allow students to diagram their assumptions about the relationships in a system, to discuss and re-interpret those assumptions with other students, and to model and then simulate those assumptions, seeing their dynamic consequence.

The tools of system dynamics can greatly enhance either type of classroom simulation. It is natural to use them with system dynamics simulations as most elements of the simulation will already be numerically quantified. This quantification makes it easy to graph or indicate what causes the elements to increase or decrease. Because role-playing simulations are broad and difficult to quantify, students will need to focus on a particular section before designing an applicable graph, diagram, or model. With either type of

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simulation, the system dynamics tools may be used as part of the pre-simulation instruction, to do problem-solving during the simulation, or within the post-simulation debriefing.

One interesting aspect of using system dynamics tools is the awareness students develop of the poor decision-making and problem-solving that exist in the real world system they are studying. If it is so easy to figure out long term viable solutions and test their efficacy by tinkering with the system (running computer models) why aren't the people in power doing it? Many students will realize that merely responding to events creates short term solutions whereas making changes in the underlying relationships of the system is more apt to create long term solutions.

IMPLEMENTING SIMULATIONS IN THE CLASSROOM

Before the Simulation

While a lead-in to any learning activity is recommended, setting the stage (anticipatory set) for a simulation is especially important because this type of activity is sometimes interpreted as a "fun" activity rather than a learning activity. In addition to getting students excited about the simulation, they need to know exactly what they are expected to accomplish/learn through their participation.

Usually it is equally important to communicate the objectives to others in the school community as well as to parents of participants. Effective communication decreases the likelihood of misunderstanding and misinterpretation. Thus you are not only communicating learning objectives but providing an opportunity for others to cooperate with and volunteer to help with, the logistics of an often complicated set-up. Through this communication process you can explain the use and value of a simulation as a learning activity. Invite constituents and colleagues to observe so they can see for themselves.

There are many ways of handling this communication and the teacher should choose those that are comfortable and most compatible with his/her teaching style. Suggestions include a letter to students and their parents, an article in the school newsletter, an informational packet for students to go over with their parents, class discussion, brainstorming, lecture with note-taking, etc. The following is a list of the points you should include in this orientation.

1. Specific learning outcomes.
2. Why a simulation is an appropriate teaching method for the content.
3. How to play a role effectively.
4. Reasons for differences between simulation and the real situation.
5. The importance of discussions and debriefing.
6. Keeping track of creative ideas, divergent thinking and unique observations.
7. The importance of and ways to uncover the dynamic system underlying the real world situation being simulated.
8. Learning how and when to use causal loops, behavior-over-time graphs, leverage points, stock-flow diagrams, computer models.
9. Classroom management: student responsibilities and teacher's role.
10. Evaluation of participation and learning including necessary record-keeping and official forms.
11. Student input to planning and improving classroom activities.

SETTING THE STAGE...direct presentation to students

The following is an example "script" of what a teacher may say to introduce a simulation.

The next learning activity which we will be doing is a simulation which means you will play roles in a model of a real life situation. Our primary purpose is to learn certain content that is part of our curriculum. I have chosen a simulation as the method of learning this material for many reasons: I think you will enjoy learning in this way, you are likely to see the importance of what you are learning, and this content is easy to learn by "doing." Here is a list of the things you should learn during this activity; your questions and comments are very appropriate at this time.

In order to make the simulation as realistic as possible it is important for us to play our roles as appropriately as we can, realizing that the people who are in these roles in the real situation are older, experienced in that job, often highly trained, and motivated to perform effectively by a multitude of pressures e.g. they could be fired! The real situation also requires a setting and equipment as well as a level of complexity that we cannot replicate. Let's identify some of the aspects we cannot replicate. (Discussion). Therefore, we must think of our simulation as a simple model which does not contain all of the aspects of the real situation but from which the principles upon which the real situation operates can be learned.

It is important to our understanding that we occasionally take time out to discuss what is happening as we run the simulation. This can increase your awareness of the process as it unfolds which affords you more opportunities for participation and learning. It is also extremely important that you jot down unique ideas that you encounter in yourselves and others as the simulation runs, to share during the debriefing. There are no right and wrong answers to any of the problems you solve or decisions you make during the simulation. Your observations may uncover valuable information about the system you are simulating. Watch for opportunities to see behavior over time, determine probable cause and effect, experiment with leverage points for changing the system or behaviors within the system, create stock-flow diagrams or other models you might construct to reflect behaviors of the system, and look for how things really work as opposed to how they are supposed to work.

Each of you will initially experience different learning based on the frame of reference you bring to the simulation. Feel free to try out your solutions and decisions and please ask for help when you need it. I will try to keep interruptions at a minimum. While you are working I will be circulating throughout the classroom observing and talking with you. I will also be responsible for providing everything you need to run the simulation as well as keeping attendance and participation records. I am here to assist as needed. It is our joint responsibility to make this a valuable learning experience.

In your team packet you will find directions for rotating roles as well as copies of all of the official forms that will be used throughout the simulation. Extra forms are available in the rack on the wall. Note that all blue forms need to be submitted to me as part of your individual evaluation, and each team must submit one copy of every green form for your team evaluation. The notes I take when I confer with teams and individuals are also used to evaluate your participation and learning. Please spend the next few minutes looking through your packets and asking questions to clarify anything you do not understand. Suggestions for changes are appropriate at this time, as well as throughout the simulation and especially during the debriefing.

Do you feel comfortable with the task and expectations? I expect this activity to last for the next two weeks but I have allowed some extra time so that we can be flexible. As always, we will negotiate your grade at the conclusion of the activity. Try to be here everyday as absences play havoc with teamwork and success. If anyone has an extended absence during the simulation, we will arrange alternate learning activities.

SETTING THE STAGE II...another way of presenting information to students.

"Our next learning activity will be a simulation; what does that mean?" The students brainstorm what a simulation might be with the teacher asking appropriate questions to keep the discussion going until all salient points have been covered. Someone (teacher, student, parent/staff volunteer) will record all ideas which can then be ordered into categories and lists as needed for clarity and closure. In this procedure all student comments are valid and recorded and most students will participate because it is safe to do so.

“According to our curriculum and the materials I shared with you at the beginning of the term, what content do you think we will be learning (evaluating) in this simulation?” Once the content is correctly identified, elicit reasons why a simulation is an appropriate method for learning this content. Judicious questioning will bring forth the points with which you want them to be familiar.

“Think about the situation we will simulate. How do you think we will have to modify the setting and equipment to fit into the parameters of our classroom and schedule?” As this discussion takes place good suggestions for use of regular classroom furniture and resources will emerge and should be noted and employed. This gives the students real ownership of the simulation as opposed to participating in a teacher-designed activity. “What are some of the significant differences between the real world performer of a particular role and the student simulating that role?” The responses to this inquiry provide students with reasons why their performances and indeed, their simulation, will not be as complicated and sophisticated as the real one.

“When we engage in simulations as class learning (evaluation) projects, each member of our group needs to assume some specific responsibilities; let’s suggest and assign those now.” Proceed to brainstorm generic tasks such as note-taking, reading, preparation of forms, grading, setting up classroom, handing in work, homework, clean-up, etc. and make sure everyone is aware of who is doing what.

“Take a few minutes right now to look over the objectives and other materials in the packets I have given each team. Let’s take a look at the forms I have used in the past and let’s brainstorm changes you think will make them more useful.” At this time project the forms on a data show or overhead projector. "Please bring up any questions or comments at this time so we can all benefit from your concerns or suggestions. The work we did today will be given to you tomorrow in written form to add to your materials."

Note: the first example was teacher directed and teacher centered. This example uses the Socratic method of teaching/learning to accomplish the same goals. With some groups of students talking “with” rather than “at” them works much more effectively. Often their questions and comments cover the points you were going to bring up and you can add those that are missed. This process increases active learning and decreases teacher talk time.

DEBRIEFING SIMULATIONS...a generic guide to uncovering the dynamics of a system.

Introduction to debriefing

As students become caught up in a simulation there can be much more learning occurring than that for which the simulation was designed. It is important for them to have the opportunity to sort out and clarify their thinking. They need to release the emotional tension of playing a role and move back into becoming themselves again. Also, “If their experiences in the simulation are not examined sufficiently, they may see the simulation as an isolated experience rather than as an experience that provides significant insights into real systems.” (Fishbanks) Students, with appropriate direction, can use system dynamics tools while debriefing simulations to uncover the dynamics underlying the real situation on which the simulation is based.

The precise strategy for your debriefing depends on your objectives. Discussion works very effectively in debriefing because students can not only try out their ideas with other students but can feed on the ideas of others to increase the depth and breadth of their own thinking. Teachers sometimes feel uncomfortable with this method because involvement varies and many students appear to be off task or not involved during a discussion while others become extremely active and involved. A teacher should feel free to use any discussion guidelines that work with his/her students as long as the free flow of ideas is not hindered nor any student denied the opportunity to share his/her thinking. Recounting of anything experienced during the simulation must be allowed and valued. At the same time the teacher can seek input from all students through judicious questioning.

Thoughts and ideas can be recorded in categories on the board as long as this does not have the effect of curtailing discussion. Standard brainstorming technique mandates that all responses are valid and should be recorded without judgment. Suggested

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categories might include: personal reactions, events, problems, intended learning outcomes, suggested improvements, dynamics underlying system, and comparison to real life situation. The teacher should provide some assistance and structure for analyzing the feedback generated by debriefing as is stated in the commercial simulation Fishbanks.

> "Whatever the goal, the debriefing generally proceeds through seven stages:
> • describe the problems and events that occurred
> • determine the extent to which those also occur in the real system
> • decide what factors in the simulation were responsible for those problems and events
> • determine the extent to which those factors are also present in the real system
> • design changes in the simulation that would avoid or solve the most serious problems
> • indicate corresponding changes that could be made in the real system
> • gain commitment from the players that they will seek to achieve the necessary changes in the real system." (Fishbanks)

SUGGESTED DEBRIEFING QUESTIONS BY CATEGORY

Personal Reactions

• What did you enjoy most about the simulation?
• How did you feel about playing your role?
• Why was (not) this a worthwhile activity in terms of learning? enjoyment?
• Why do you think the teacher had you work as members of groups in the simulation? What did you learn from this?
• What do you think some long term effects on you may be resulting from this experience?
• What emotions did you experience as you did the simulation?

Events

• What were the main events of the simulation?
• What decisions were you asked to make?
• What is the difference between long term and short term effects (consequences) of your decisions in the simulation?
• What do you predict they would be in the real situation?
• What kinds of trade-offs or compromises did you make during the simulation?
• What trade-offs do you think may be necessary in the real situation?

Problems

• What problems did you encounter in making decisions or as a result of your decisions?
• What caused those problems?
• Do the events, decisions and problems occur in the real situation?
• Are the causes of the problems similar in the real situation?
• Can you think of some ways to change the simulation to avoid those problems?
• Would those changes also work in the real situation?

Suggested Improvements

• How could the simulation be improved so that you and/or others learned more?
• What other simulations could we create to extend our learning?
• What additional kinds of learning might occur if we ran the simulation for an extended period of time?
• Would this be worthwhile?
• In what ways is the computer a valuable tool to help you run this simulation?

Learning Outcomes

• What new learning took place for you during this simulation? (Consider what you learned about working together in a group, curricular objectives, the real world situation.)
• What things you already knew took on new meaning?
• In what aspect of the simulation did you learn the most? What did you learn?
• What kind of connections to things you already knew did the simulation open up?
• What is it about the simulation that caused this to take place?
• How would you explain the difference between acting in a play and playing a role in a simulation?

System Dynamics

• Why do you think the teacher used a simulation for this material?
• Once you have run a simulation, why isn't it possible for you to return and replicate the experience?
• Explain how the impact of your decisions during the simulation might not be evident until a future time.
• How do you think delay between actions taken and seeing the results of the actions affects decision-making in the real world?
• Explain how people could measure long range impact of decisions.
• How did using SD tools help you in your work?
• Where did you observe effects becoming causes? Explain.

Real World

• Describe this simulation's connections to (is it part of) a much larger situation.
• In what ways did your decisions during the simulation affect the whole situation? How did that make you feel?
• What are some decisions you made that have not been tried in the real world situation? Why do you think that is so?
• What leverage points did you locate; did intervention at those points accomplish what you wanted?

FOLLOWING FORMAL DEBRIEFING...how to increase understanding of System Dynamics

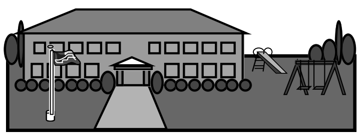
At this point you should have reached closure on the actual workings of the simulation and can extend learning through focus on the dynamics underlying not only the simulation but the real world situation on which it is based. Building on their responses in appropriate categories, help students use the tools of system dynamics to facilitate a deeper analysis and a more thorough synthesis.

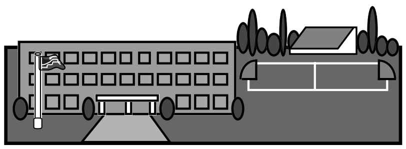
They can isolate a particular behavior and construct a graph to show the changes in the behavior over time.

Classroom *continued on next page*

Build New Schools or Wait? continued from page 1

several high tech companies, is growing rapidly and several schools are at or over capacity. The district opened a new high school and middle school two years ago and they are already at capacity. This influx of students, new bond measures, and the marked impact on buildings, students, and teachers presented a perfect opportunity to look at this problem from a systems perspective!

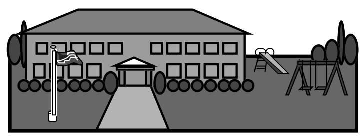


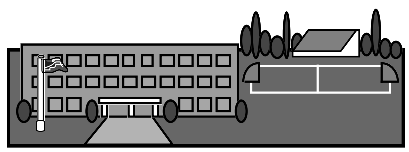


Dynamics learned

One of the great aspects of building a model is the discovery of the unexpected. (Indeed, sometimes the unexpected means that the model has gone awry, but in this context I mean a positive "ah ha" type of unexpected!) In many respects, the core of the model is a population model. What factors affect population? Besides births and deaths, the next obvious factor is immigration and emigration. Of course, people coming in don't all go to schools. Rather, it is a fraction of them that are actually students. To obtain this info, I talked and gathered information from specialists from Metro Regional Government, Portland State University's Center for Population Studies, and Beaverton City Planners. Another key factor is the limit to growth. Looking at building records and present zoning laws, the city planner made an educated guess at the carrying capacity for Beaverton and this was integrated into the model. It is possible to build new schools that will not be fully utilized if they are built at the top of the population growth curve. Some school districts make the mistake of seeing rapid growth and reacting without looking at the big picture.

The information on pre-kinder and school age children was obtained fairly easily from my district. In working with the model, it is evident that the size of the schools and bulges at certain grade levels become extremely important when trying to make long term decisions. The lag time (the time to pass a bond measure and actually build a school) also presents planning challenges. Finally, the issue of building portables versus building a whole new school or schools is a complex problem. Certainly, building portables can release some of the pressure of overcrowding but they have their limits.



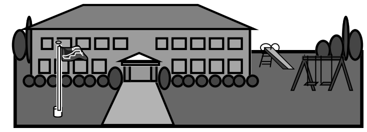


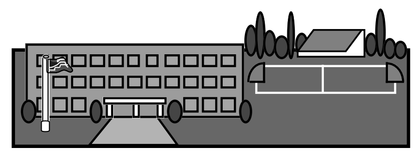
Working with the model

The model itself allows you to build new schools and keeps track of the number of times you have too much capacity or when your schools are overcrowded. On a later screen, you can run the simulation again while manipulating zoning laws, building taxes to discourage new construction, and high density housing. All of the essential statistics, school sizes and capacities are presented at the start of the model. Working with the model itself exposes a complex and dynamic system as it related to Beaverton, but a person from another district could easily put in their own figures to get a grasp of school growth (and or decline) in their district.

On a final note, this model has been presented to a superintendent, an assistant superintendent, the head of technology, a principal, and over 40 teachers. As you might have guessed, several people have posed "what if" questions about growth, school funding, and architectural designs. One of the great things about working with Stella is the ability to factor in more assumptions, test them, and discuss them with colleagues. The only limiting factor so far has been, alas, the time to create more!

Matt_Hiefield@bsd.beavton.k12.or.us
Matt's models are available from the CLE or on the wwweb at http://sysdyn.mit.edu/





Effective Use of Simulations in the Classroom

continued from previous page

The interaction of variables can be shown with causal loop diagrams indicating leverage points for change. Quantities that change over time can be modeled as stock-flow diagrams and STELLA models with the quantities as stocks and the policies the relationships that influence the flows.

Summary

The focus of this paper has been to encourage teachers to enhance their instructional methodology and their students' learning through the effective use of role-playing and system dynamics simulations. The skills students acquire and the thinking they do as they run simulations should lead to the development of citizens who will be more informed and able to take an active productive role in their world.

The complete text of this article with appendixes is available from us or the web site.(http://sysdyn.mit.edu/)

Information about STELLA Models

All the CLE models are STELLA for Macs. They are named (or can be named) so that PC's can also recognize them.The transfer from Mac to Windows or vice versa is pretty simple. The following is taken directly from High Performance Systems' Frequently Asked Questions page on their website (**www.hps-inc.com**):

Can I translate my Mac models to the PC and visa versa?

Absolutely; the models are completely transferable between platforms. However, you do need to identify the models as ithink or Stella files to the respective platforms.

To move a Mac model to the PC:

Change the model name to 8 characters or less.
Add the file extension to .itm for ithink models and .stm for Stella models.

To move a PC model to the Mac:

This is slightly more complicated. The Macintosh keeps its file information internally so you must use a tool like PC Exchange*, ResEdit or Type Resolve to designate the Type and Creator information for that file according to the table below:

ithink
Mac File Information
Type:
ithm
Creator:
ithn

Stella
Mac File Information
Type:
STM2
Creator:
STL2

Note: Upper and lower case must be input as shown!

*We recommend PC Exchange because you can set it up once and then all future Windows files will add the correct type and creator information automatically as you copy them over.

Please let us know if you have any further questions.

Jason Bourne
Customer Services Group
High Performance Systems
support@hps-inc.com

STELLA models can easily be sent electronically as attached files.

You too can join the K-12 Discussion Group
(k-12sd@sysdyn.mit.edu)
To join contact Nan Lux: ***nlux@mit.edu***

New Materials Now Available from the CLE or the Web Site

from the CATALINA FOOTHILLS SCHOOL DISTRICT, TUCSON, ARIZONA

CIVILWGR ***Causes of the Civil War.*** Greg Reid
5 one hour lessons for 5th grade students. Through viewing relationships and systems, the learners will be able to graphically describe the tension in the US and the various causes of the Civil War. Students will evaluate the success or failure of strategies that people use to resolve conflict. ($1.00 - paper copy)

COLLEGCF ***The College Finances Simulation***. Catalina Foothills SD
This STELLA simulation is designed to help students understand how actions taken today can affect future events, and what/how things can affect college funds. ($1.00 - paper copy)

EFFECTJC ***Effective Use of Simulations in the Classroom.*** (Martha) Jane Dunkel Chilcott
This paper provides information that will help teachers understand what a simulation is as well as when and why to use one. Both system dynamics simulations and role-playing simulations are explained and related to each other. Detailed information is provided to help teachers implement simulations in the classroom. ($2.00)

ENZYMERH ***Properties of an Enzyme - Catalase***. Rick Heupel
An activity for high school students where they will examine some of the properties of an enzyme called Catalase, using a STELLA simulation model to investigate the effects of various conditions on the catalyzing rate. ($1.00)

FRIENDPC ***Friendship Game***. Peg Clemans
In this game, students are introduced to the concept of reinforcing relationships, as well as the idea that practicing their friendship skills could not only lead to a friendship but could also make more friendships likely. (50¢)

HOMEWORK ***Homework Responsibility***. Catalina Foothills SD
A model showing behavior over time to demonstrate how the interaction of various factors influences student grades and that desperate, lasts ditch efforts to bring up low grades doesn't work. (50¢)

MESOAMCF ***Mesoamerican Coexistence***. Catalina Foothills SD
A Social Studies simulation on the Spanish Entrada into Mexico in 1519. Three sets of activities compare and contrast Mesoamerica prior to the Spanish Entrada, with the Entrada, and with Spanish-Mesoamerican trade. ($1.50)

PRECIVGR ***Pre-Civil War Tension Simulation***. Greg Reid and Scott Suter
A STELLA simulation which will enable students to identify causes of the Civil War and view different reactions to these causes. The students will understand the rise in tension between the North and the South during the pre-Civil War period.

TOOLSP-N ***The Use of Selected Systems Tools in Various Areas of the Reading Curricula and Classroom Management***. Mary Ann Pierotti and Thuy Ngo
Designed to be incorporated into the 5th grade curriculum throughout the school year, the focus of the project is to teach students to think and act systemically by introducing them to selected systems tools to various content areas. Included are specific lessons meant to be part of a classroom management plan and reading units throughout the year. ($2.00)

WIZARDCJ ***System Dynamics and the Wartville Wizard***. Caryl Jones and David Whitaker
A simple language arts lesson, based on the story "Wartville Wizard" by Don Madden, which is easily extended to social studies and science units, and is also adaptable for K-5 and beyond. (50¢)

WOMENS-R ***Women in WWII.*** Scott Suter and Greg Reid
Designed as a cumulative activity for the 5th grade after studying World War II, this STELLA simulation demonstrates the changing role of American women during World War II. ($3.00)

WWISIMSS ***World War I Simulation***. Scott Suter
This lesson is designed to be used as a review/extension activity after the 5th grade students are familiar with the events associated with World War I. The simulation allows students to evaluate assumptions about what may have happened based upon different times the US could have entered the war. ($3.00)

from the CC-STADUS PROJECT IN PORTLAND, OREGON

BUILDNMH ***Build New Schools or Wait?*** Matt Hiefield
A School construction decision-making simulation. (50¢)

from the GIST PROJECT in BRUNSWICK, GEORGIA

MIDDLESK ***An Introduction to Systems Thinking and System Dynamics for Middle Grades.*** Steve Kipp
This unit was written to introduce middle grades students to some simple but powerful tools that represent a small part of the Systems Thinking/System Dynamics discipline. Suitable for a teacher with little or no experience in ST/SD. ($3.50)

from OTHERS

JOURNACZ ***Reflective Learning Journals***. Dr. Carol Ann Zulauf
The insights and key learnings that students wrote in their own journals when learning to think systemically. (50¢)

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Updates . . .

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Carlisle, MA.

The Carlisle Public Schools are holding their third Carlisle Education Forum on February 1, 1997. These forums have been designed to help create community discussions about issues in Education.

Peter Senge and Tom Snyder were the speakers at the two previous Forums.

This year the speaker will be Jay Forrester, speaking on Learning through System Dynamics as Preparation for the 21st Century.

If you are interested in attending please e-mail or write Deb Lyneis, 25 Rutland Street, Carlisle, MA 01741; Lyneis@aol.com.

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