GAMING TO IMPLEMENT SYSTEM DYNAMICS MODELS

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Operational games based on System Dynamics models have been used in System Dynamics teaching since the first days of the field. Already in the text *Problems in a Industrial Dynamics* (D. Packer, MIT Press, 1962) was described the simple production distribution exercise, widely known as "the beer game." This game is so effective that it has been used in almost every introductory System Dynamics course over the past thirty years. Nevertheless, until the early 1980s there were essentially no further efforts to develop and use System Dynamics games, except for a few management-training exercises developed by consulting companies.

Then two System Dynamics games attracted interest to this technique. In 1983-84 I worked with Donella Meadows and a team of colleagues at the International Institute for Applied Systems Analysis, Laxenburg, Austria, for one year to create STRATAGEM, a System Dynamics-based management training game. The exercise was created for use in a course that was to be conducted by the US Agency for International Development for its senior energy and environment program officials in Latin America. We demonstrated this game to all the participants attending the 1984 System Dynamics Conference in Oslo, Norway. That session combined with John Sterman's success in using the Kondratiev Cycle game he and I created at the IIASA during the same period has generated a still-growing interest in this technique.

The variety of activities associated with gaming have become my principal focus in the field. Over the past six years I have personally created four, major System Dynamics games, and I have supervised development of perhaps a dozen more. I have arranged for STRATEGEM to be translated into six languages and manufactured into about 3000 sets, which are now used in about 30 countries. I have personally conducted game-based training sessions in over 20 countries, and I have taught several university courses on the design and use of games. I am also Associate Editor of the major journal in the field, *Simulation and Games*. From these sources have emerged a variety of new insights, concerns, and priorities related to gaming as a technique for the implementation of System Dynamics models. This paper briefly summarizes my present views on the potentials and the pitfalls of gaming.

Before one goes very far into a discussion of implementation, it is essential to be clear about the precise goals of any specific effort to convey insights that are derived from System Dynamics analysis. There many levels of System Dynamics expertise, and the process of implementation of may be directed towards conveying any one of them to the student or client. In Figure 1 I list seven different levels of competence.

Figure 1: Seven Levels of System Dynamics Expertise

Level	Competence
#1	understand the system
#2	carry out a specific decision
#3	implement a recommended policy
#4	modify a mature model
#5	construct a new model
#6	teach others to build new models
#7	guide organizational change

It is important to note that most formal, university-based teaching programs have been designed to convey fifth or sixth level competence -- the capability to construct a new model or teach others how to build new models. As we know this is a time consuming and expensive objective. Several years of training may be required before someone becomes really competent at these levels. But few of our graduates ultimately become teachers and only a small percent more work professionally as model builders. It is as analogous to a military academy that spends a million dollars each in training recruits to be a pilots even though most of them will graduate from the program to become infantry.

Often our goals will be achieved with real world systems, even if we convey only second or third level competence -- teaching people enough to carry out specific decisions or to implement a particular policy. Gaming can be an important tool in achieving any one of these seven levels of competence, but I will focus my remarks here on its use to convey understanding of the system and to change the system through a specific decision or policy.

To understand the special contribution that gaming has to make, it is useful to recall a Chinese proverb:

When I hear, I forget. When I see, I remember. When I do, I understand.

The efforts by system dynamicists to convey understanding of the system or to help clients decide on carrying out a specific decision or implementing a particular policy have traditionally been based on spoken and written presentations of model results. The expertise conveyed by these presentations is typically shallow and short-lived. But when you embed a System Dynamics model in a game and give the client "hands-on" learning, you put him in a "do" mode, and this conveys real understanding.

Many different types of activities may be defined as games, but my remarks here refer to a fairly specific set of exercises. The games of interest to me always: involve more than one player, force participants to interact in decision making, include physical pieces (boards, markers, etc.), and use a System Dynamics model as the referee or environment for the simulation. These games always involve several iterations of a basic decision sequence, rang-

ing from five one-year cycles in my AIDS game to the ten five-year cycles that are required in STRATEGEM. After each cycle the decisions are entered into a System Dynamics model which calculates out the consequences of players' action and specifies the starting condition for the beginning of the next cycle. This is very different from video games in which one person alone interacts with the computer.

This kind of gaming provides many functions that are useful in programs for training and implementation. In Figure 2 I list six of these functions.

Figure 2: Six Functions of Gaming

- motivate learning
- create a metaphor
- convey principles of system behavior
- enhance the group's skills in communication and decision making
- evaluate specific decisions
- provide a context for systems research and model evaluation

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The process of gaming is highly engaging. A well-run and well-designed game quickly captures the excitement and the enthusiasms of the players; it strongly motivates them to learn. It has often occurred that I propose a break after a three- or four-hour game session, only to be told by the participants that they prefer to continue the session a while longer in order to test out some additional ideas. It never happens to me after lecturing three or four hours that the audience insists that I continue once I have announced the opportunity for a break.

Gaming creates a situation within which players can experience a wide variety of complex phenomena that have been previously unfamiliar to them. Through reference to specific arrangements of physical pieces on the board or particular patterns of social behavior that occurred during the game, those who have shared participation in a game acquire a stock of metaphors that are useful subsequently in their discussions to assess and extrapolate behavior in the real world.

Games are an extremely effective way of conveying principles of systems behavior. They can help the participants personally experience some of the basic behavior modes that are important in real life. Because a game can compress into an hour or two the experience of phenomena which normally occur over decades or more in real life, this is an extremely important function. For example, in STRATAGEM I help participants experience the demographic transition, a phenomenon that occurs over 50-100 years, and the debt explosion that can collapse a nation's international financial system, a phenomenon which may take 10-30 years. Lectures about these same phenomena cannot possibly convey the feelings, motivations, and perceptions of policy makers who produce these behaviors in real life; all of those are instilled in the players by the game experience.

Because games of this sort discussed here involve ambiguous data, complex goals, uncertainty, and the input of many participants, they replicate important aspects of the real problem

situation. But games reveal the consequences of decisions quickly, and they permit experimentation, with policies too important to permit mistakes in the real world. Thus participation in gaming can quickly enhance a group's communication skills and improve its ability to make effective and efficient decisions.

A game which has been extensively tested and for which a very detailed and typically expensive data acquisition effort has been carried out can also approach reality close enough that it becomes useful for testing the probable consequences of specific decisions. Be aware, however, that creating a game at this level of detail can often involve development costs of $100,000 or more. And the result is typically of interest to or available to only one small set of participants.

Finally games also offer a context for research and evaluation. It is possible to create a game about some real world issue and then use as players people who have expertise in the real world. Their comments about the content and the operation of the game quickly points out errors and deficiencies in the underlying model. This approach to model testing, somewhat similar to Monte Carlo model simulations is a much more demanding and powerful test than that available to us through the application of traditional econometric approaches.

To exploit these many useful functions there is a growing effort to develop and use System Dynamics games. As is the case with most new fields, practitioners are drawn into the field without the necessary background in formal theory and practical experience. As a result many of the gaming efforts not particularly effective. There are many mistakes and dead ends. I have identified six potential pitfalls of gaming, which should be of concern to those using this new tool. They are summarized in Figure 3.

Figure 3: Potential Pitfalls of Gaming

- spend too little time on debriefing
- neglect the other methods of teaching
- become preoccupied with computing and networking technology
- neglect the integrity of the model
- ignore the requirements for comprehensible mechanics
- offer operators too little training in the conduct of the game

Because it is so engaging to play games there is a great danger that the operator will spend to little time on debriefing. This is a serious mistake. Perhaps 60% of the value of a gaming effort is lost if it not followed immediately by a debriefing session that links the game experience back to the real world. As a general rule of thumb, the debriefing session deserves at least as much time as was devoted to the game itself.

Because gaming is an attractive and powerful tool there is also the tendency to rely too much on this one technique of learning. It has been said that if your only tool is a hammer everything will look like a nail. I have seen people, newly enthusiastic about gaming, begin to assume that every single training and implementation goal can be achieved by the

development of some new game. This viewpoint imputes too much power to the technique, and it also forces one into a prohibitively expensive line of development. It is very expensive and time consuming to create an effective new game.

A more appropriate role of gaming may be illustrated by several 40-hour workshops that I have developed for managers. For example, worked with Norman Marshall and Thomas Fiddaman to create a week-long course on medical drug logistics for African district health officials. We put about 10 games into this workshop, and they enormously enhanced the impact of the course. But the total time devoted to gaming was not more than about eight hours, just 20% of the available time. Most of the games in the course were very short, just 15-30 minutes each. We had an hour-long game, and one that required about five hours. The effectiveness of these games was raised considerably by use of lectures, reading assignments, videos, case study discussions, roundtable discussions, and group projects.

A third danger in the use of gaming is that we become too preoccupied with the technology. I have seen people get carried away with local area networks or graphic displays or a particular type of software like spreadsheets. They force the game into a form which will use the specific technology that has become the object of their infatuation. The result is that the shortcomings or special features of the technology shape the game experience so that it has little relevance to the social or economic situations within which the insights must eventually be applied.

One example of this danger was provided by the MIT effort to convert the STRATAGEM II game on the Kondratiev Cycle over into a form that required only a video display and no board, pieces, or paper. I found that this adaptation made the exercise much less interesting and much less relevant to the corporate clients for whom it was designed. Another example are the international relations games played by electronic mail. I know that the very special features of terminal-based electronic mail systems are so different from the face-to-face interactions involved in real crises that the game has little to teach us about reality.

A fourth pitfall involves the quality of the model and its technical documentation. All modelers have a problem documenting their model and testing it thoroughly. Of course I believe System Dynamicists have less trouble in this regard than modelers working through other system paradigms. We must strive to prevent the enthusiasm that meets most games from giving us licenses to sustain sloppy modeling practices.

A fifth difficulty is to ignore the requirement for simple and easily-understand mechanics of play. I have often seen an elegant System Dynamics model embedded in a game exercise whose mechanics were so confusing that the players spent the whole game session trying to understand what to do next instead of interacting with the underlying causal model. Little learning occurs under these circumstances.

A final pitfall comes from the fact that games are often widely distributed. Their appeal is so great that people who have played a game only once will often adopt it up as a part of their own training tool kit. But learning how to play a game is very different from learning how to operate it. I can teach you to play STRATEGEM in about 20 minutes. I can teach you how to play successfully in about an hour. In contrast, it normally takes me 15 to 20 hours to convey the skills required for conducting a successful STRATEGEM session.

To avoid the spread of games among those who err in their use, we should work much harder to create support materials and to design operator training sessions that will let them use the tool effectively. This is not a minor task. I find that even a simple game can often require a 50 or 100 page user's manual in order for it to be documented adequately.

I expect as System Dynamicists' use of gaming matures these pitfalls will decline in importance. In Figure 4 I identify four steps that can be undertaken to raise our benefits from gaming and to reduce the potential problems.

Figure 4: Next Steps in Development of System Dynamics Gaming

- develop a family of games each incorporating one of the generic SD models
- design and offer training programs on the skills required to operate the games
- develop the basic principles and tools of model evaluation based on gaming
- establish guidelines for integrating the use of games with more traditional teaching methods

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We need to reverse the historical tendency to focus our efforts on the design of new models. Indeed the insights present in the tried and tested models of the past are sufficient for drastic improvements in many systems. Our first step should therefore be to take the well tested generic models and develop them into a family of games. This is no small undertaking. When we began to develop STRATAGEM we had a working model within a week. It took six months more of hard work by three people before we had a smoothly functioning and mature game.

We should begin to design and offer training programs in the operation of games. Conducting a game is an interesting combination of theater, system science, didactics, and social psychology counseling. However, there is already a good literature in the field and a number of training programs which can be the basis for our efforts.

Third, we need to think through the process of model evaluation and to design the definitions, criteria, measurements, and statistical methods that can take data from gaming sessions and use them as the basis for a model evaluation and system conceptualization.

As a final step, we should work harder to develop objective guidelines for integrating games with other teaching methods.

This agenda spelled out in Figure 4 is an ambitious one, but I am confident that we can succeed in carrying it out. During the last six years I have found that gaming taps in analysts, teachers, and students, an enormous reservoir of energy and enthusiasm. A well designed game experience offers learning at a much higher level, and it is incredibly more satisfying for teacher and student alike. As we put the members of our field in touch with this new energy source, I expect that gaming will grow quickly over the next decade to become an extremely important tool in implementing system dynamic models.