Issues In Designing Interactive Games Based On System Dynamics Models

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INTRODUCTION

The advent of the micro-computer revolution brings about the potential for people to increase their understanding of our environment. Technologies are becoming available that enable people to become more active learners about their environment. Along with technological advance, system dynamics modelers are paying more attention to gaming environments as a means to increase the interactions that a wide variety of game-players or audiences have with system dynamics models. That is, by creating easy to use and graphical gaming interfaces, users are able to interact directly with a model with little or no prior training. Throughout the iterative gaming processes, they can learn not only the system under investigation, but also the relations that give rise to the phenomenon of interest: "Learning by playing around."

However, it is difficult to find general guidelines on how to create computer-based games, or, how to design gaming screens. Many researchers wishing to move into the area of gaming can look at existing gaming situations and attempt to emulate the best features of existing games. Although the "How to" depends upon the research purpose, the researchers and the game-player's interests, the time frame of game, etc., general principles for designing games would reduce the ambiguity and the uncertainty in designing games in new areas, and heighten the utility and the applicability of the state of the art. This research proposes to advance our understanding of how to create gaming screens to support simulation-based games such as one linked to the STELLA software package. The research will document the experience of two teams of experts - one system dynamics modeling team and the other team of psychologists expert in human judgement and decision making - as they interact to create an interactive gaming simulation. In other words, the main purpose of the research is to examine issues that will be of use to modelers who are beginning the process of building system dynamics-based games. These issues will both reflect on "best practice" and attempt to articulate unresolved

* Authors are listed in alphabetical order. The work reported here is highly collaborative. This paper has emerged as a product of an on going seminar on dynamic decision and system modeling at the Rockefeller College. The authors express appreciation to other seminar participants for their help in developing the concepts presented in this paper.

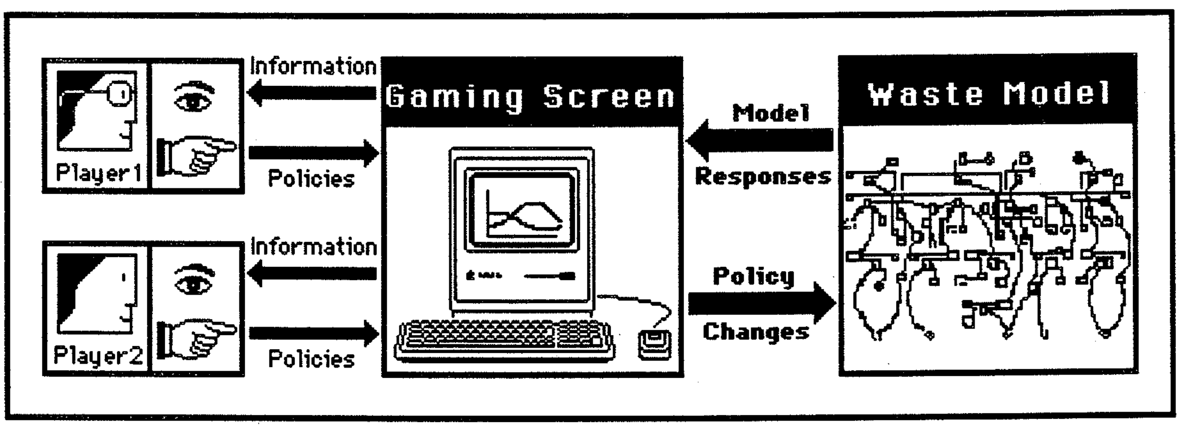
issues based upon interactions with the two expert teams.

The case chosen for study will be the financing of solid waste disposal in New York state, focusing on the mutual responses of the state and the local governments in the presence of a waste crisis. The research proceeds by documenting the various versions of the gaming screens that have been developed during several iteration of the development process. After this history of the project is given, reactions and suggestions from both system dynamics and judgement experts are summarized into a series of issues. These reflections are based upon a research journal that documents how and why various versions of the gaming interfaces were developed.

Solid Waste Model

The various versions of gaming screens, created with the STELLAStack software and discussed below, are designed to interact with a System Dynamics model of solid waste management, WASTE1. WASTE1 is a computer simulation model of solid waste generation and management for New York state including both state and local governments. The model simulates the complex interactions among the behavioral, environmental, technological, and economic variables that influence or are influenced by, state and local actions.

Within WASTE1, there are eight interacting sectors: Solid Waste Generating Sector, Landfill Sector, Incineration Sector, Recycling Sector, Environmental Sector, Regulatory Sector, Solid Waste Management Sector, and State Government Sector. The Management Sector consists of five sub-sectors: Solid Waste stream Allocation, Development Planning, Budget Request, Budget Funding, and Budget Allocation sub-sectors. It is assumed these interacting sectors and sub-sectors endogenously generate the present solid waste problems and determine the effectiveness of various policy interventions.



(figure 1: relation of game-players, gaming screens, and waste model)

Unlike other existing solid waste model most of which address aspects of the waste problem at a single point in time, WASTE1 presents a dynamic picture of the component variables over time. By taking a dynamic approach, WASTE1 provides a strategic view of the solid waste issue, thereby anticipating the timing, nature, and magnitude of the solid waste system's response to alternative policy scenarios (Mashayekhi 1988).

Originally, WASTE1 was programmed with the Professional Dynamo software. It was transferred to a model of the STELLA software for the purpose of facilitating the creation of visualized gaming screens. Figure 1 shows the relations of game-players, gaming screens, and solid waste model. Gaming screens play a dynamic role of connecting complex models and game-players unfamiliar with the inner operations of the models. Through gaming screens, game-players receive information on the major variables in the solid waste system. The information perceived by game-players is an important basis for making policies or changing policies in response to the solid waste problems. Each game-player can actualize his policy changes by clicking on policy buttons or by changing the position of policy levers appearing on the gaming screens. On the other, gaming screens directly communicate with the solid waste model. Gaming screens display, graphically or numerically, the changing trends of the major variables in the solid waste model. Gaming screens also convert the policy changes made graphically by game-players into numerical changes within the waste model.

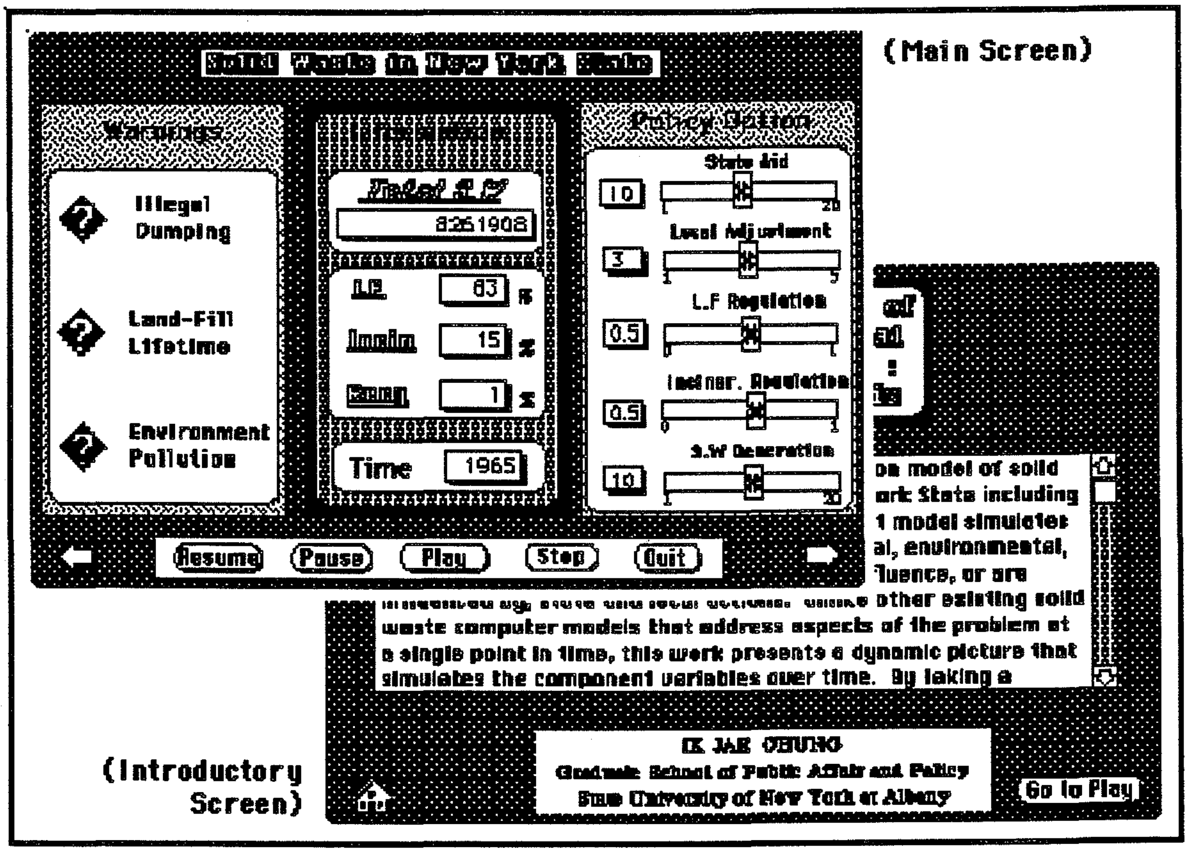
DEVELOPMENT OF GAMING SCREEN

First Gaming Screens

The first gaming version (GAME1) of solid waste model includes two major screens: the introductory screen and the main gaming screen (figure 2.) The introductory screen contains a scrollable field that indicates a general description of the solid waste model (WASTE1) and the gaming version of the model (GAME1), the structure of the GAME1, and the gaming rules, etc. A click on the "Go to play" button on the lower right side of the introductory screen leads to the main gaming screen.

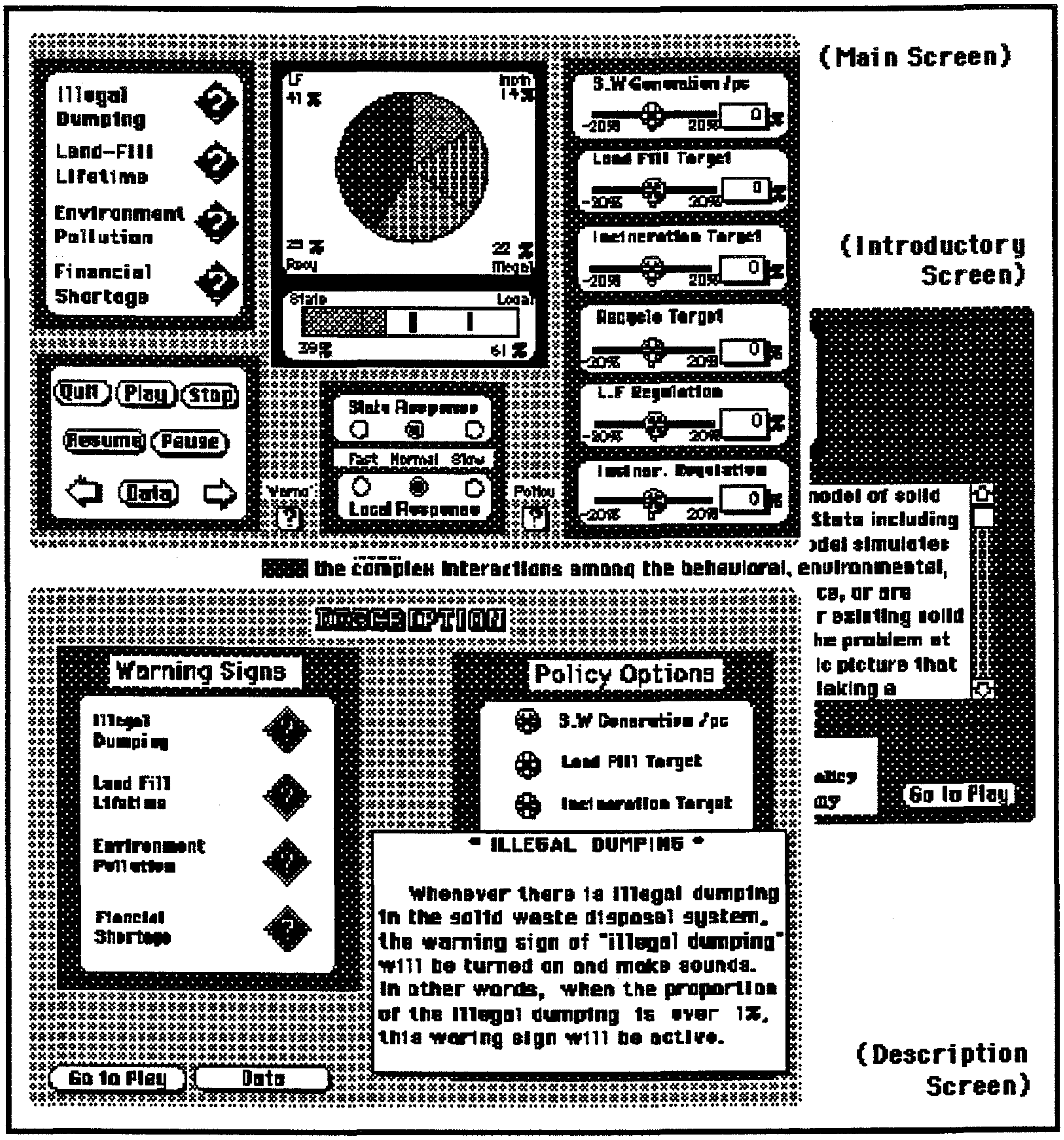
The main gaming screen consists of four sector: information sector, policy sector, warning sector, and operation sector. In the center, the information fields show the overall performance of several major variables -total solid waste generation, dumping rate, incineration rate, recycling rate, and the current simulation time. On the left hand side of the gaming screen are warning signs which let game-player know there are problems. When the value of a variable corresponding to a specific warning sign is greater (or less) than a pre-set threshold value, the warning sign will flash and make a sound. Located in the lower part of the main screen are the buttons for operating the game. On the right hand side are policy levers. GAME1 has five policy options: State financial aid, Local financial adjustment, Landfill regulation, Incineration regulation, and Solid waste generation per capita.

For the screens of GAME1, one of major reactions or suggestions from research teams indicates the limited number of policy options. The five policy levers available in GAME1 can not meet the possible policies or policy combinations of game-players in dealing with the solid waste problems. On the other hand, each policy options is named so general or inclusive that game-players may interpret a policy option in different ways. For example, the policy option "State Financial Aid" can be interpreted as a state tax reduction in the business of disposing solid waste, as a budget transfer from other state government's projects, or as a tax increase in the waste-generation related business. Besides ambiguity of policy options, the scales of the existing policy levers also make game-players unclear about the strength and the direction of a policy intervention. The policy button "State Financial Aid" is designed to vary the delay time of a certain number of years, ranging from 1 to 20 years, in providing the necessary financial aid from state government to local governments. Without some detailed explanation of this option and practical knowledge or experience in budgetary processes, it is difficult to anticipate the realistic implications of this policy intervention. Similar problems are also found in the other policy options of GAME1.



(figure 2: screens of GAME1)

Research teams also suggested some alterations and additions in displaying information. First of all, a main research focus of this study is on analyzing the dynamic financial responses of game-players in dealing with solid waste problems. From the main screen of GAME1, however, game-players do not have any information, indicators, or warning sings regarding the financial status of solid waste system. Second, most information in GAME1 is numerically presented. Although numbers are a precise and easy way to display information, they are not always the best and the most efficient method. Within a dynamic situation, a graphical or animated data presentation would be a better way than a discrete numeric display. Especially, it may be difficult for game-players under dynamic gaming environments to figure out relatively small numeric changes of a variable with a large value, such as the variable of "Total solid waste generation." In a sense, the graphical data presentation takes fuller advantage of the graphics capabilities within the StellaStack software. Third, the information on the simulation time, the information field named "Time," is found to be redundant information. Once the game starts, the StellaStack software displays the simulation time on the upper right corner of the gaming screen as a default function.



(figure 3: screens of GAME2)

Second Gaming Screens

Based upon research teams' findings and suggestions on the first gaming screens, the second gaming version (GAME2) of solid waste model was created (figure 3.) GAME2 included new policy options such as Landfill capacity expansion target, Incineration capacity expansion target, and Recycling capacity expansion target. A warning sign for "Financial Shortage" was also added. In order to clarify the strengths and directions of policy interventions, policy options were re-scaled to proportionally vary a range of -20% to +20%, wherein 0 % means no changes in a policy option or continuation of the current policy. The policy options of "State government financial aid" and "Local government financial adjustment" were changed from a ratio-scaled policy levers to a ordinal-scaled policy buttons including three policy buttons of "slow," "normal," and "fast" responses.

A new screen containing detailed descriptions of each policy option and warning sign was appended. A click on the question-marked buttons named "Warning" and "Policy" in the lower center of the main gaming screen leads to the policy (or warning sign) description screen. Within each part, all names of warning signs (or policy options) are listed. Whenever game-players click on a button next to a specific name of warning sign or policy option on which they needs some detailed descriptions, a explanation field appears. The description screen in figure 3 shows an example of describing the warning sign of "Illegal Dumping." On the lower left corner of the description screen is the button of "Go to play" which brings back the main gaming screen.

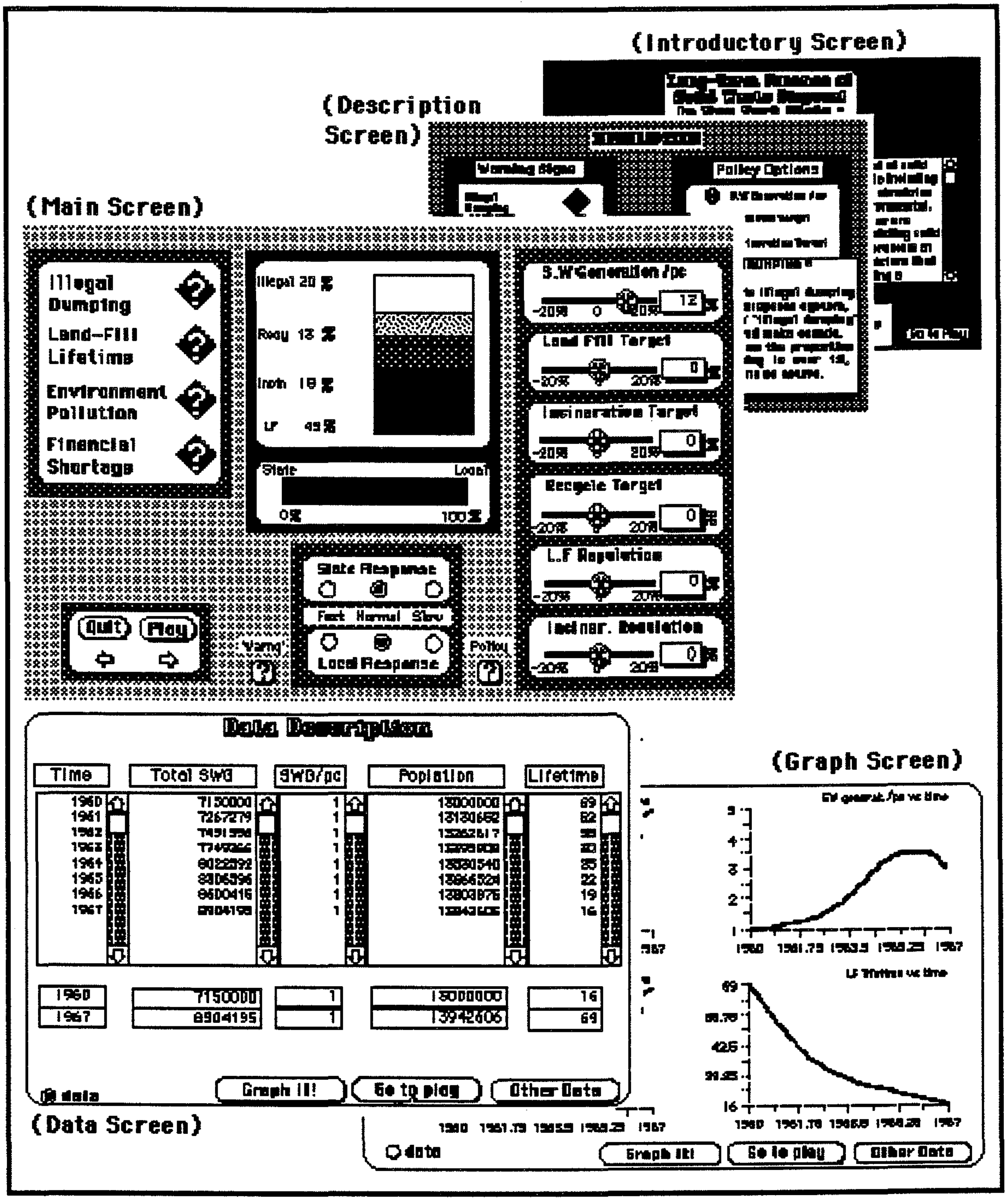
The information on the performance of solid waste disposal is graphically displayed along with numeric information. That is, the overall size of pie chart was designed to change as the amount of the total solid waste generation changes in the system. The size of a specific pie section also changes according to the relative amount of a waste disposal stream. A barometer was included to show information on the financial share of state and local governments. For example, the main gaming screen in figure 3 says that 41% of the total solid waste generated is dumped in landfills, 23% recycled, 14% incinerated, and 22% is illegally dumped. 39 % of the total budget in managing solid waste is covered by the financial support from state government, and the remaining budget (61% of the total budget) is supported by local governments' resources.

One of the major comments on the screens of GAME2 is that the main gaming screen is too complex for game-player to perceive and handle the available information. The screen has 8 policy levers or buttons, 10 performance indicators or warning signs, and 10 operation buttons. One way to reduce the complexity is to create a hierarchical structure by categorizing the policy options on the basis of the common policy implications. The 8 policy options can be categorized into 4 policy groups; solid waste generation group, disposal capacity group, regulation group, and financial response group. Within each policy group, specific policy options are available. Instead of presenting specific policy options on the main screen, for example, the main screen can be re-designed to include 4 buttons of policy groups. A click on a button of policy group can bring a screen which contains specific policy levers or buttons.

Another suggestion was to store the data of major variables and policy changes during gaming. The stored data can be used not only to analyze the dynamic behavior of game-players, but also to provide retrospective information over time to game-players under a gaming situation. For the purpose of providing retrospective information to game-players, the stored data can be presented in an accumulated numeric form or in the form of time series plots.

Third Gaming Screens

We encountered a technical difficulty in designing the animated pie chart in the main screen of GAME2, the overall size of which is designed to change according to the total amount of solid waste generated. Thus, the third gaming version (GAME3) of solid waste model presents the information on the performance of disposing solid waste by an accumulated bar graph (figure 4.)



(figure 4: screens of GAME3)

In order to save the space on the main screen and to reduce the complexity of the main screen, some operation buttons were made invisible in a certain gaming situation. After playing the game for several rounds, we found that only two operation buttons, instead of five buttons, are sufficient to handle the gaming procedure. Before starting a game or after playing a game, game-players should decide whether to "play" (or re-play) a game or to "quit" gaming. Once a game starts, game-players' possible choices would be to "stop" or to "pause" gaming. When they pause a game, they would "resume" the game or review , "data" accumulated during gaming. The main screen in figure 4 shows a game that has been stopped. In sum, the main screen contains one of three pairs of button; Quit and Play, Stop and Pause, or Resume and Data.

GAME3 includes an additional screen for describing accumulated data during gaming. A click on the "Data" button on the main screen leads to the data description screen containing scrollable fields in which numeric data of major variables are accumulated over time. A click on the "Graph it!" button on the lower part of the data description screen clears up the numeric data and data fields, and graphs time-series phase plots on the basis of the numeric data.

We found that the gaming screens did not provide sufficient information on public reactions. This problem relates to a more fundamental issues for designing gaming screens; "Who are the game-players?" and "Who are the audiences of the game?" Depending upon "Who," one policy option would be more important than the others; one warning sign more meaningful than the others.

ISSUES IN DEVELOPING INTERACTIVE GAMES

We have found that the issues relating to the development of interactive games can be broadly divided into three types--issues relating to the definition of the game's purpose, issues relating to assumptions and approaches taken toward user psychology, and finally issues relating to gaming technique. Each of these are discussed in turn.

Defining the Game's Purpose and Approach

The issues that arise in the design and conduct of a game are largely determined by decisions about the purpose and approach of the game.

1. Clarify "Meta-Purpose". Borrowing from the metaphor of a game as flight simulator, games can have four overarching purposes: (1) to help users understand the principles of flight, (2) to train users to "fly" the system, (3) to help users design systems that can fly better or in a more stable fashion, and (4) to conduct basic research about what are the characteristics of the best managers who "fly" our systems. Each of these purposes invokes different psychological assumptions about the users (see below) and implies very different learning objectives.

Potential meta-purposes In our solid waste case include a) helping users become wiser consumers about the options open to manage solid waste (understanding the principles of flight), b) having users choose policies that will result in the management of solid waste ("flying" the system) c) having users design (in a simulated environment) better policies (designing a system that "flies" better), or d) doing more basic research on how users react to the solid waste crisis. Each of these purposes is best served with a different game.

2. Tune and Re-tune your Model's purpose and structure to your Game's Meta-Purpose. Just having a good system dynamics model does not mean that you have a model that is well-suited

to serve as the basis for a game. (Graham et al 1989) A good model may be designed to serve a purpose that is not aligned to the assumptions or purposes of the game that you want to build. We began thinking that we wanted to build a game based upon the WASTE1 model and wound up deciding that we needed to build a model based upon the game we were designing (once we got our meta-purpose clarified per point 1 immediately above.)

3. Clarify Roles and Points of View in the Game (Applies to all meta-purposes). A common problem in building simulation models that take a system wide view is that that model's point of view may be more global than any single actor in the system and hence a difficult point of view to play and learn from (who is the manager in the World Dynamics study?). Depending on the game purpose, it may be important for users to play a role that they can identify with. For some purposes, however, it might be helpful for users to play a role they are not familiar with.

In our solid waste model, we found that we were trying to create persons who had a system wide perspective on the solid waste crisis, but the levers and policies that would be of interest to real players arose from their particular point of view. We needed to build multiple points of view into the game.

4. Think Through Player Interactions During the Game. Games may be a one player game. In which case, other points of view are being simulated closed loop by the simulation model. Meadows (1989) has suggested that learning can be maximized when players are interacting with other humans playing roles as well as with the gaming model itself. When this is the case, the purpose and design of the model must extend to designing interactions between multiple players.

5. Focus on Dynamic Insights (Applies to meta-purposes 1,2 and 3). As we have already suggested, teaching dynamic insights, that is nuggets of insight based on feedback thinking, may be the hardest learning objective of all. Something as simple as writing down the lessons of the model and the game in simple sentences is a good way to keep this focus in mind. The system dynamics literature is full of suggestions of generic dynamic insights such as the phrases "worse before better behavior" or "shifting the burden to the intervener". Often dynamic insights for a game can be seen as more specific manifestations of these general ones. We believe that in order for users to learn better to operate a system, these dynamic insights must be integrated into their causal textures.

In our solid waste model we noted for example that failure to invest in the decades of the 1980s and 1990s in solid waste disposal capital led to illegal dumping in the late 1990s and beyond, driving up overall costs considerably. Or early investments in landfill capacity created a critical reserve capacity to deal with the crisis during the delay necessary to bring on line recycling and energy recovery capital solutions. Failure to anticipate these siting and construction delays led to illegal dumping and large future costs.

Assumptions Concerning User Psychology

While the whole field of system dynamics is devoted to being clear and explicit about assumptions concerning the system being modeled, practitioners often make loose and implicit assumptions concerning who are model and game users and how do managers and users interact on a psychological level with our models and games.

1. Work with a Clear Theory of the User's Cognitive Functioning (Applies to all meta-purposes). System dynamics models are complex, feedback-driven causal explanations of how the world works. For persons trained in creating system dynamics models, it is quite easy to make the (erroneous) assumption that users' mental models contain (or should contain)the types of details that we put in our formal models. Vennix (1990) has identified a diverse set of measurable characteristics that can all be contained within users' mental models. This type of understanding could be called "design logic". That is, it contains the level of complexity and detail necessary to design, build, or modify a system. This is the kind of detailed understanding that a mechanical engineer would need in order to design a better automobile. It is most appropriate for meta-purpose 3 above.

However, if the game is designed to serve meta-purposes 2 or 4, the users will typically be system operators, not designers. Consequently, they are properly tuned to "operator" rather than to designer logic. For example, it is perfectly possible to operate an automobile safely being totally ignorant of the logic that went into its design. Although knowledge of the details of the workings of automotive systems may help improve person's driving, such design knowledge alone is not sufficient to operate the automobile safely.

If we begin building models and games with the implicit assumption that managers and users are as interested in design logic as we are as model builders, we may be led into creating confusing or complex learning environments that do not take into account the reality of what managers both want to and need to learn. This mistake is more likely in a gaming environment where the details of the system's complexity (e.g., the design logic) is hidden from the user behind an apparently simple user interface.

Some insights into the form that "operator logic" should take may be provided by psychologists who are interested in how people cope with (i.e., "operate") systems under uncertainty and complexity. Although most of the research to date has focused on static systems less complex than most dynamic models, theoretical perspectives have been developed that might help guide the developers of dynamic games. For example, a central concept in the theories of the psychologist Egon Brunswik (1935) is the "causal texture" of the system. Causal texture includes all interconnections and relations among the variables in a system. In a dynamic model, the causal texture is specified by the model itself. However, a person confronting a complex, uncertain, environment does not have such a clear representation of causal texture and must infer it from experience (or learn it from others).

In Brunswikian theory, causal texture is represented by a matrix of correlations among variables. The correlation is considered to be the fundamental unit of cognition. In addition, there is a long and successful tradition of using multiple regression techniques to model human judgment processes. This research suggests that, in some applications, gaming screens designed from a correlation and regression perspective might be more effective than screens designed from a system dynamics perspective. Comparison, and integration, of these perspectives is a promising topic for future research.

2. Be Clear about What are Your Learning Objectives (Applies to meta-purposes 1,2, and 3). Users can learn many things from a game. For example, they could learn what is the universe of policy options, what are the possible outcomes, how do outcomes vary with different actions,

that the system is complicated and difficult to manipulate, that the system has many feedback loops, and so on. In some cases, a game could even be designed where we do not care if the user learns anything. For example, a game designed to complete research on manager's reactions to dynamic situations may not have at all the objective that users (often students recruited from our classes) actually learn anything.

Most often system dynamicists claim that they want users to learn "dynamic insights" or clear nuggets of insight gleaned from a deep understanding of the feedback at work within a system. However, users oriented toward operator logic are much more likely to learn points other than these most difficult points to teach unless dynamic insights are clearly identified as the ultimate learning objective.

3. Focus on Policy Levers and Outcomes (Applies to all meta-purposes). Games should begin with a clear depiction of what can be done (i.e., policy levers) and what is the universe of outcomes (Andersen and Rohrbaugh 1983). If dynamic insights are to be built, the model must build squarely on what users experience as feasible action steps and believe to be important outcomes. If the game does not "connect" to user's prior beliefs concerning the causal texture of the underlying system, they will be unable to learn important lessons from the gaming exercise.

4. Be Sensitive to Individual Differences. What means are considered feasible and what ends are considered desirable are psychologically determined variables as much as they are given properties of the reality being modeled. What I value as an output may be irrelevant or worse yet of negative value to you (Gardiner and Gord 1983). Games must provide a wide enough range of policy and outcome variables as well as allow users to scale their own preferences so that individual user differences can be accommodated.

5. Do Not Expect Users to Learn from Outcome Feedback. A persistent result both from the psychological research literature as well as the system dynamics gaming literature (Senge (1989), Vennix(1990), Sterman (1989), Bakken (1990),) is that users simply can not learn complicated lessons about a system just by playing a gaming simulation. That is, information concerning how well one does in playing the game, in and of itself will do little to improve user's ability to play the game or learn the system. Avoid the easy tendency to build a game just to be played.

6. Focus on a Cognitive Debriefing. This point is tied quite closely to the observation above that humans can not learn well from outcome feedback, especially feedback that comes from interacting with a feedback system. For true learning to occur, especially learning that is focused on dynamic insights, lectures, workbooks, or other group exercises must be designed to help students reflect on the game being developed.

The designed audience for our solid waste model was secondary school students in New York State. Our debriefing sessions were planned to be integrated with other material being developed for the New York state curriculum on solid waste education.

Gaming Technique

In the end, assumptions about user psychology and one's overall approach to the game must be implemented in specific game building techniques. Below are some of the specific issues that we believe to be important in this arena.

1. Build in Player Positions/Points of View and Player Interactions. This point is directly tied to the points just made above. In our exercise, we experienced an overload of information being packed into only a few screens. After all of the policy options and outcome variables were finally crammed into these few screens we both cognitively overloaded our users and confused them about how to play or why they were playing the game. In reality, game players pay attention to fewer cues but care more intensely about those cues. For example, elected officials may care intensely about the Not In My Back Yard (NIMBY) syndrome and pay great attention to siting proposals, but not necessarily be concerned about air quality regulations. By dividing the game into discrete and more well-defined points of view, users were more able to play a position and were less confused about what data deserved their attention. We also could solve our screen data overload problem.

System-wide issues often arise from players who have a well-defined point of view as they interact. That is, system wide problems arise from various actors all pursuing their own self-interest. These issues are ideal to be included into a debriefing session or structured into player to player interactions during the game.

2. Plan for Debriefing Sessions. For the reason just mentioned and many others, debriefing sessions must be planned as part of any game. Users can not learn from outcome feedback and important lessons (certainly dynamic insights) can only be learned with some form of cognitive feedback and reflection. Debriefing materials are fully as important as are the gaming materials themselves.

3. Be careful with the Definition of Model Concepts and Variables versus Users' Own Concepts. Summary cues that appear on the gaming screen have very precise meanings within the simulated environment. For example, our model had a warning light for "environmental pollution" that went off when certain limits were reached or a policy lever for "land fill regulation" that allowed users to tighten or loosen regulatory constraints. While each of these cues had well defined meanings within the context of the simulated environment, we discovered that users new to the system responded to these cues as broadly ambiguous. Some users expected responses almost in the opposite direction from the one written into the model code or could not predict what the policy lever meant nor what would be the first order consequences of selecting that lever (let alone the feedback consequences). We found it necessary to build in help screens to make more of the model detail available to users. But matching users' broad conceptual categories to the more precise categories of the model proved to be tricky and needed quite a bit of attention.

4. Use Gaming Interface to Bridge from Event Logic to System Parameters. One of the reasons that users may have had difficulty with model concepts is that many users are accustomed to thinking in discrete event logic. For example, users would prefer to think about "having every

house separate its newspaper and plastic". In our model, these events by individual households might translate into a parameter relating to fraction waste separated. While users could appreciate the cognitive impact of certain events, they were much less prepared to think in terms of system policy parameters.

We suggest that in designing gaming interfaces, the game should be able to "translate" between user logic which is often discrete and even-oriented to the broader policy parameters typically used in system dynamics models.

5. Be Heavy-Handed with Teaching Points. If a game is designed to teach students either to operate a system or to design policies within a system, we can not emphasize enough the need to clearly build into the game, student interactions, and debriefing materials a clear statement of the point--of the dynamic insights being generated. There are so many contextual factors that users can concentrate on (how to use the keyboard, what the colors on the screen mean, how many policy options there are, how does this action work--the list is seemingly endless) that it would be a miracle if users took away the lesson that you wanted them to unless it was pointed out (repeatedly) in a heavy-handed fashion.

In one game designed as a basic research tool into how decision-makers use data in a dynamic decision-making environment, Richardson and Rohrbaugh (1989) tried to give away an optimal decision-making rule by having it prominently displayed on one set of screens. Even with obvious cues such as these, many users missed the points that the game designers were trying to make.

6. Build Models that Have as Rapid a Response as Possible. We had quite a problem with the solid waste model in that the basic system trajectory (continuing growth in solid waste generation and the slow construction of alternatives to landfills over a multiple decade period) did not change rapidly no matter what policy levers users pushed. Many dynamic systems, especially those moving through sigmoidal growth into an equilibrium exhibit this characteristic. What users are doing is to manipulate the long run equilibrium of the system and to divert marginally its transient path. These slow moving dynamics are boring to watch and one comes away with a feeling of frustration. In our case, we believed this to be the true dynamics of the system. This was an unfortunate problem that we had to work around.

7. Exploit Software Capabilities. It seems hardly necessary to state that having zippy graphic capabilities build into the user interfaces greatly enhances the fun both in building and in using these games. Be curious about what the software can do and push it to its limit. In our example, we had some trouble creating pie charts that could dynamically grow and shrink. But hammering against this problem taught us more about the software and led to improvements in other parts of the display.

8. Take Full Advantage of Screen Space. There are two constraints in utilizing the space of a screen; physical (or spatial) constraint, and psychological (or cognitive) constraints. The former means that a gaming screen, usually computer monitor, has an absolute spatial capacity to display numbers, figures and graphs. The latter constraint means that game-players have cognitive limitation in perceiving performance indicators and manipulating policy levers under gaming environments. If gaming screens provide too many indicators and levers,

game-players will experience cognitive overload. In designing a gaming screen, therefore, try to maximize the spatial utility of screen within the cognitive capacity of a game-player.

SUMMARY

This paper has reported on one attempt to create a gaming interface based on Mashayekhi's model, WASTE1 (1988). Based on that experience, we have tried to articulate a laundry of issues that must be confronted by modelers who wish to experiment with creating such user interfaces. These issues can be broadly grouped into assumptions about the psychological bases of users' mental models, approaches to defining a game's purpose and approach, and finally specific gaming techniques.

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