Simulation of a System Collapse: the Case of Easter Island

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Introduction

The purpose of this paper is to show how a Learning Environment can enable users to gain insights into the rise and fall of the Easter Island civilization. This Learning Environment allows the user to simulate and to understand the basic structure of a particular system, and the behavior which it generates and shapes. The concept of a Learning Environment is described, and a generic learning framework developed, in Peterson (1990).

The setting is Easter Island, an isolated windswept place of brooding mystery, where the land is covered with over 800 monolithic statues known as *moai*. Worldwide, many people find a connection between the rise and fall of a complex Neolithic culture based on limited resources, and today's problems of sustainable development on a global scale.

Architecture

The architecture consists of a brief introductory sequence about the purpose and setting of the Learning Environment, followed by the main menu comprising the activities: exploring, playing, and understanding why. The purpose of the introduction is to create a feeling of mystery, and to motivate users.

Exploring: The immediate need for the user at this stage is for information and guidance about how to learn some system thinking skills needed to analyze the problems.There are two main aims for this activity. The first is to provide the user with a set of information about Easter Island based on recent scientific research. As well, the user is encouraged to check relevant information about other Polynesian islands. The second main aim is to employ a systems thinking paradigm. In this way the user is enabled to discover what creates the problem.

The user embarks on a journey to Easter Island in a time capsule. By clicking on a timeline the user can navigate to significant historical periods, listen to "interviews" with Easter Islanders, and also with the first European voyagers to reach Easter Island. The user can find out more about key terms in a hypertext glossary. At another layer, and integrated with the hypertext, a guide enables the user to

distinguish between patterns and events, to understand how problems unfold over time, to improve this skill through sketching graphs of behavior over time, and to develop some of the "seven critical thinking skills", Richmond (1997), in order to come to an understanding of the underlying structure.

Playing: There are three simulation experiments. In each case the design of the interface is well defined, similar, and allows the user to exercise autonomy. The control panels have a maximum of three performance indicators and five policy levers.

(1) The user is encouraged to write down what actually happened on Easter Island, giving assumptions and reasons. Then the user sketches dynamic paths for the expected behavior of important variables. The user can run the model to compare expected and actual results.

(2) The user then takes on responsibility for the welfare of Easter Island, writes a mission statement of goals and strategies, and moves the sliders on the control panel and runs the model to achieve the desired results. In this experiment the user takes on the role of an hereditary chief of the powerful Miru clan. The user, as leader and decision maker, has to balance long term global concerns, such as the need to maintain peace, with shorter term clan concerns. Promoting the construction of a limited number of statues generates a reinforcing feedback loop. More statues mean a stronger sense of tradition which increases social cohesion, which increases information flows and trade, which increase food production,which leads to an increase in population, which encourages more statue production. But statue building comes at a price, as the need for rollers and ropes to move the completed statues causes the level of forested land to decrease.

(3) For the simulations in (1) and (2) the parameter for the base rate of forest regeneration is relatively low, reflecting actual conditions on Easter Island. In (3), the user is now able to change parameters related to forest regeneration and to the degeneration of cleared land by moving sliders on two control panels. The user then writes another mission statement of goals and strategies and makes decisions on the main control panel.

Understanding Why: The final part is an analysis and debriefing. The user can see not only what happened and why, but also how leverage intervention points could be used to generate alternative "as if" scenarios. For example, given certain relative shifts in the model parameters governing regeneration of forested land and the degeneration of cleared land, an alternative scenario is logistic population growth which moves into steady state. Some effective decisions can be counter-intuitive, as shown in a series of classic studies by Jay Forrester (1961), (1969). The user can click on the why? button to explore interdependencies and the main types of feedback structure.

Simulation Engine

The underlying simulation engine of the Learning Environment is an economic model constructed using the STELLA software. An agenda for linking economics with systems thinking, broadly conceived, and going beyond mainstream economics, was initially proposed in Fox and Miles (1987). The theory embodied in the model is endogenous, with the causes of the problems found within the system itself. There are four main components of the model: a definition of sustainability based on an extended concept of wealth; exponential growth of population; a basic structure of stocks and flows; and a simple allocation sector.

The first component is a definition of sustainability, based on an extended concept of wealth, following the World Bank(1995). Wealth is regarded as consisting of four types of capital stock embodied in natural capital, produced assets, human capital and social capital, each of which generates a stream of outputs. For example, human capital is embodied in the skills and knowledge acquired by an individual, while social capital, the least tangible of any of the types of capital, is embodied in relations among persons, including trust, networks, and information flows. The meaning of sustainability is that the total stock of capital that we pass on to future generations, in differing combinations among all the types of capital, should not be less, and may be more, than the present stock

Exponential growth of population and its relation to the stock of capital is the second component. The model is intended replicate the events on Easter Island, as far as we can know them. The behavior of the Easter Island population is a story of exponential growth, after a long period of consolidation, followed by overshoot and collapse

The third component is a basic structure of stocks and flows which generates reinforcing and counteracting feedback loops. The model begins by identifying each of the four types of capital as a stock with a system level. The flow rates that cause the system levels to change are then identified. Each stock usually acts as a cause, enabling patterns of behavior to take place, and may act as a buffer between inflows and outflows. When net outflows are positive the level of a capital stock will decrease.

The fourth component is a simple allocation sector, with the usual economic assumptions of scarce resources and diminishing returns. However recent research suggests that these assumptions may not always hold, Arthur (1990). On Easter Island a complex network of exchanges grew out territorial control by clans and subclans, specialization of skills, and diversified resource bases. In general, clans in the north and west specialized in fishing while agriculture was carried out in the south and east, Bahm and Flenley (1992). The extent of property rights on Easter Island is uncertain.

There are six main sectors in the model; population dynamics, social capital, natural resources, food production, production of statues, and resource allocation. Boat building is covered in a smaller sector. The model is simple but generates complex behavior.

Conclusion

The paper has outlined the way a specific Learning Environment can be used to enable users to gain insights into the rise and fall of the Easter Island

civilization. As in any Learning Environment, the user is offered "hands on" access to an underlying simulation engine to run simulations as a way of directing the learning process. The insights and the pace of the learning process are unique to the user.

To be sure, a Learning Environment using Easter Island as the setting lacks the immediacy and media focus of such current problems as acid rain, river pollutants, deterioration of the ozone layer, and extensive forest cutting. Yet concerned folks see Easter Island as a microcosm of planet Earth. As with Stonehenge, places of mystery have an inherent fascination. Feelings of awe are mixed with the need to find out more. How? and Why? questions draw in the user to see things through the eyes of a people far removed in space and time, different from ourselves.

The aims of the paper are limited. Other related work addresses questions about the meaning and definition of sustainable development, and the reasons why the population dynamics and the extent of resource depletion on Easter Island were different from those of other major Polynesian islands.

Work in progress

The above use of STELLA in economic modelling forms part of a wider research program using systems thinking / systems dynamics to analyze economic processes.

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