'Big Chief': The Utilisation of Model Building for the Design of Science Education for Sustainable Development Games.

Timothy Barker[1]

Abstract. A model building paradigm was employed to inform the design of a game for Science Education for Sustainable Development (ESD). The intention is that such techniques should be readily achievable by university level students as they recontextualise game design to their locale. Hence, they not only produce a game which can be played in their community but they also begin to understand the complex processes underpinning the sustainable development of their own locale. Consequently, the game design process is elucidated together with one particular illustrative model. Finally, results for this model are presented before conclusions concerning the validity of this rationale are reached.

1 RATIONALE

There is a need to further engage both the public and the scientific community further in the issues concerning what has come to be known as Sustainable Development. It is true that today these issues have a degree of social currency yet aside from the sensationalism do people really understand the complexity inherent in a sustainable future? Furthermore, how does one communicate these complexities in simple terms in which individuals who may not have received the training in the necessary ways of thinking can understand with the minimum of effort? Further still, how does one contend with the many varieties of people who need to understand these issues in a global context? These are some of the questions for ESD.

2 OVERVIEW

In the context of this research project we are proposing that one way to communicate the diverse range and complexity of ideas to a large audience may be through the development of a game. There is a history of game usage in ESD and an academic journal dedicated to the theory of game design. More importantly though games have been shown to increase participants' motivation to engage with educational materials [1]. That is, the association of games with fun and leisure time may be leveraged to help achieve some of the aims of ESD, notably higher acceptance of the concepts being explored.

However, we are proposing a two stage process in this game scenario. Firstly, having decided what the game should roughly be about students should adapt a (or construct an entirely new) model of the game playing process. This model should be based on local conditions wherever the game is hoped to be played. Thus, the idea is that the game itself will be more relevant to those who will be playing it thereby helping to increase its applicability to their lives and hence increasing acceptance. Further, if ideas for local interventions were to develop based upon the game then these also would be more suited to the locality.

Secondly, the same students who produce the model should use it to test the various interactions of variables in order to decide what the rules of the game should be. For example, which resources (e.g. people, fish, water, fertiliser) do the 'pots' represent, what kind of potential disasters (e.g. war or disease) are represented by the dice and how many beads (counters) are needed for each pot? All of these answers should become apparent when the model is developed.

With an idea in mind of the basic category of game (inspired by an African genre of game called Mancala) it is necessary to decide what your 'pots' and 'beads' represent. Further you should decide what is to be 'painted' on your dice. Questions you could ask yourself may be:

1. what factors influence how well the people do in the context, e.g. rainfall, good weather, animal migration paths, etc (these could be on your dice)?
2. what factors influence how poorly people fare in the context, e.g. disease, war, political situations, etc (these could be on your dice)?
3. what do people do? do they plant crops? do they walk for miles to a water hole? do they work? do they look after huge families?
4. what happens in the land around the people? do animals wonder freely and are hunted? does the river bed often dry up? which animals prey on others? which animals are useful to humans?
5. is there any industry in the area? are there huge farms nearby? are there any kinds of factories? do local people work at the factory? is industry (or people) polluting the area?
6. what do you know about the science of the area? is the lake saline? what is the soil composition? what is the most used form of energy? what is the 'best' form of energy?
7. what is healthcare like? is it a long walk to the hospital? is 'western' medicine used? is there a traditional healer nearby?

Box 1. Typical Student Model Design Questions

[1]DIYNGO (www.diyngo.org). Email: dr.timothybarker@gmail.com

3 THE MODEL

Box 1 shows typical questions for students to consider when designing their rules for the model. 'Pots' include 'people', 'crops', 'fertiliser', 'irrigation', 'eagle', 'water', 'fish', etc. Additionally 'people', 'crops', 'plants' and 'fish' each have two further 'pots' called 'r' and 'k'. The reason for these extra pots is that a formula known as the Verhulst equation is used to derive the cumulative population of these 'pots' over time. It basically states that a population grows by factor 'r' until a 'carrying capacity' (e.g. the amount of food or land, etc.) is reached. However, as the 'carrying capacity' is gradually being reached the 'growth factor' gradually diminishes. This is quite common sense as one could easily imagine that if there is little food to go around a population, for instance, then it is likely that they will grow less and of course the more they grow the less food there is. The result is a logistic curve, typically a sigmoid function (see Figure 1).

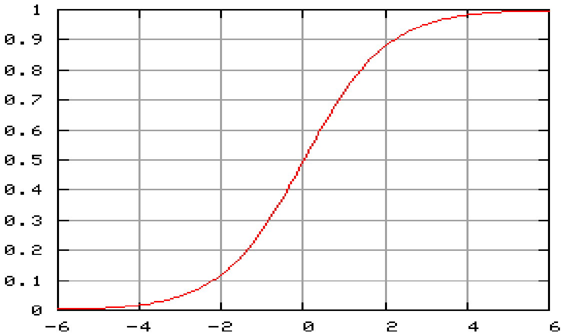

Figure 1. Logistic Curve[2]

Students were asked to develop the model in Excel. The first column in each Excel 'sheet' contains the heading 'year'. Thus as we descend the spreadsheet each subsequent row represents the next year. Hence we can see how the years, in our case 25, affect the growth or decline of 'beads' in the 'pots'. We use several sheets to represent several 'villages'. Theoretically, all of the 'pots' could be on one 'sheet' however, for the sake of legibility on the screen we utilise these various 'sheets'.

4 RESULTS

The model, once established, can be run any number of times as students explore the interplay of changing variables. For example, Figure 2 shows that a high amount of fertiliser entering the lake causes more pollution when the lake bank is not so healthy resulting in fewer fish for the eagles to feed on eventually leading to their extinction.

5. CONCLUSIONS

Model building can be a joyful experience particularly as one experiences the interplay of variable, or 'pots' in our case, which were unforeseen. This is, in some ways, the joy of the process of scientific discovery. On the other hand, when one is tweaking formulae and trying to mimic nature in all its glory through the divination of mathematical creativity this joyful process can, at times, become rather annoying. However, it is worth persevering during the most painful moments of creativity as, as ever, the end product can be well worth the pain.

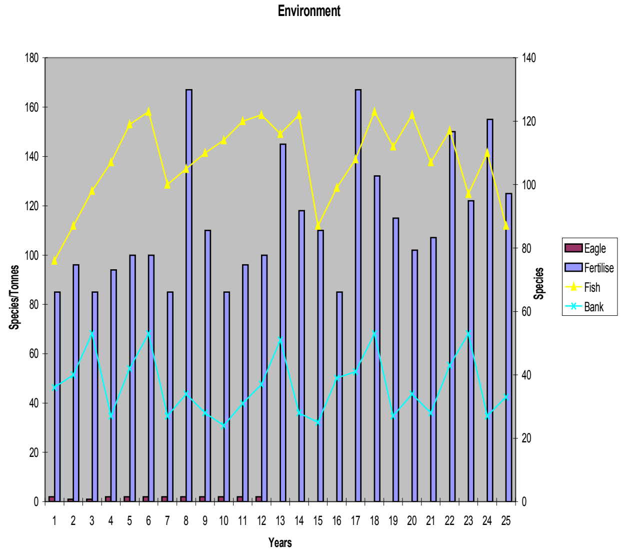

Figure 2. A Bad Year for the Eagle
(Fertiliser = 30, Land = 10 for all 3 chiefs)

Likewise, the problem with building a model is that the work is never done. However, we all know that models are *representations* of reality and, as such, are *approximations*. This is worth bearing in mind as a result is interpreted and subsequently acted upon. For this reason a model should be 'run' a great deal of times and results aggregated over these 'runs'. Further still, the well practiced Scientific method of consensus amongst peers could also be of use. More importantly the originator(s) of the model would do well to point out its weaknesses and limitations before, what may turn out to be, unfounded conclusions are acted upon.

In this light it is wise to point out that this model has many limitations. Indeed its correlation to the reality it purports to represent is, at best, of such a coarse scale that, in terms of scientific accuracy it may be dismissed by some out of hand. However, this model is an **educational tool**, it is a vehicle with which to commence discussions, to stimulate interest in the fundamental principles underlying Sustainable Development. That is, that social, economic, environmental and cultural (at least) systems are all interrelated and that misusing one can have untold effects upon the others. As such we believe that it, and more importantly the method, are useful aids for ESD.

REFERENCES

[1] Barker, T. & Morrison, E.(2008). How to Make Physics More Interesting or Learn Science and Save the World! *JETL*, University of Leicester (see www.timothybarker.com)

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[2] http://en.wikipedia.org/wiki/Verhulst_equation (accessed 12/2/07)