Learning about Sustainability through Experiencing Complex, Adverse Conditions Typical of the South: Reflections from the African Catchment Games Played in Finland 2008

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***Abstract*— The African Catchment Game is an innovative role playing game which was played twice in Finland in 2008 as part of the CIMO funded collaboration between Finland Futures Research Centre and Rhodes University. It simulates a "real imaginary country"[1] and enables participants to explore and experience how southern countries may or may not develop scenarios of sustainable resource extraction and consumption. New processes modelling climatic variability, water management and consumption were introduced for these two game runs. This imaginary country has roles for an urban/industrial sector, the informal sector, trading intermediaries, overseas trade, a government comprised of a president and two ministers, peasant and commercial farmers. Chapman's original game, Green Revolution Game/Exaction, is based on systems and complexity theories from the 1970s and 1980s. Our modifications to Chapman's game are underpinned by theories of Complex Adaptive Systems and educational approaches based on constructivist, active/experiential learning models.**

The paper presents an analysis of the two Finnish games from the perspectives of the participants and the game managers. Participants' information came from pre and post game questionnaires and the focus group discussions that were part of the debriefing process. These two methods enabled us to examine the local and network processes which developed during the games. Global scale processes of production, consumption, resource utilization, trading and water provision was collected by the game managers as part of their management processes throughout each game run. Our analysis shows that the participants' understanding altered and deepened as a result of playing the game. The nature of the game, as a Complex Adaptive System, and the constructivist learning approach through which the game is experienced means that lessons of a more universal nature cannot be extrapolated.

I. INTRODUCTION AND BACKGROUND

The educational underpinnings of the African Catchment Game can be traced back to Piaget's constructivist theory of learning[2]. This asserts that knowledge is not transmitted directly from one person to another through face-to-face teaching, but is rather built up by the learner through exploration and discovery. The learning process can also be seen as a social activity, following the ideas of Vygotsky (1896-1934), and is not limited to a solitary process. Social constructivism refers to how a learner constructs knowledge in a social context, such as a simulation game, by making personal meaning from socially shared perceptions[2]. The student is an active agent, making meaning in his/her life and in so doing, constructing knowledge[3] in a joint enterprise with the facilitator of their learning activities[4]. Knowledge is created by making links between new information and experience and the existing knowledge base. These links are either in the form of adding to, modifying, or reorganizing existing knowledge and/or skills. Unless one makes these links, the new knowledge remains isolated and is not used effectively for new tasks or in new situations[2]. The ability to encode information, as well as the retention and retrieval of information, is critical for effective learning.

Role-playing simulation games such as the *African Catchment Game* allow students to construct their own knowledge through their experiences. In the past we have used reflection exercises as assessments[5] to ensure that understanding has been consolidated after the simulations. Typically the reflections require participants to describe and reflect on what they have experienced and then connect this to theoretical literature or constructs. The simulations in Finland used a more sophisticated approach with pre and post game questionnaires designed to map changes in participant's understanding against a theoretical model of water in the environment. This is introduced later.

The ACG has been adapted from Graham Chapman's Green Revolution Game that dates back to the 1970s[1 6]. The Green Revolution Game is a role-playing simulation modelling modernization amongst rice-growing agricultural farmers in South Asia. Chapman[1 6] made use of systems thinking, complexity theory and field data to develop this game. He saw that there was a lack of conceptual understanding about rural based agricultural farming amongst students that called for a different teaching approach. The simulation game provided students with the opportunity to wrestle with the inter-relationships that are bound to the decision making processes associated with developing farming strategies[1]. Later modification to the Green Revolution Game had an urban sector, with industry, commerce and a government. This was Exaction produced in collaboration with Elizabeth Dowler of the London School of Hygiene and Tropical Medicine.

Chapman's Green Revolution Game would fall within what Walford[7 8] has described as the development and refinement stage in the use of games and simulations in Geography. Our own modifications to GRG fall within the final stage of acceptance and stabilisation that typically comes some 25 years after the first stage. The ACG models the southern African context and includes commercial farming, debt, cattle, sustainable development and HIV-AIDS. For the 2008 simulations in Finland[9] we developed new environmental components, a dam and a river system, modelling different rainfall patterns in the catchment's areas to facilitate understanding and appreciation of the inter-relationships of water management, food security and economic development. This was done in collaboration with the academics running postgraduate programmes studying water management processes at Rhodes University. One particular interest was to model recent understanding of the increasing uncertainty of rainfall and extreme climatic events.

In the c30 years since Chapman first designed the GRG the systems thinking which underpinned the game has evolved. The multi-disciplinary field of Complex Adaptive Systems (CAS) has developed steadily from the mid 1980s and now, as its name suggests, embraces ideas of complexity and adaptation. The ACG has been constructed from the early 1990s and, as Walford[8] suggests, this has been through modifying an original game concept to new circumstances and contexts. Theoretically and methodologically we now can understand and analyse the games through using Dooley's[10] nominal definition of Complex Adaptive Systems. The principles described below and the different levels at which they operate help us to understand how very complex games such as the ACG operate. We can also use them as methodological lenses through which to analyse the two game runs.

A CAS operates through three principles:

- order emerges within the system but it is not predestined;
- change within the system is not reversible, its history cannot be repeated;
- outcomes cannot be predicted in a simple linear way from the components, agents and processes existing within the system.

Agents (role players in our simulations) operate within the system, adapting to their environment in positive and negative ways, developing schema for survival, growth or change. The strategies adopted and rules formulated by agents are, however, dependent on incomplete or biased information and the flows of resources or information in the simulation can be impacted on by positive or negative multipliers depending on the complexity of the system and who is connected with who. Agents have tags which identify or encode their roles and these may be combined into aggregates or meta-agents. Examples of ACG meta-agents are the roles of President, Minister of Water and Minister of Home Affairs. There are also agents and meta-agents sitting partly outside the CAS who determine the rules of information and resource flows within the CAS. In the ACG these are the three game managers.

A Complex Adaptive System typically operates at three different levels and the analysis below examines what happened in the simulations at these levels[11].

- For the local level, through the agents themselves telling us about their strategies and understandings (schema) in the pre and post game questionnaires,
- At the network level where both the managers (as participant observers) and players reflect on the self-organization of the simulation, who was connected with who, where resources and information came from etc. This is aided by photographic and video recording.
- For the global level, through examining macro-level performance indicators collected by the managing meta-agents on spreadsheets as the simulation unfolds.

The results section below focuses on the local and global levels with some supplementary information at the network levels.

Water and food, together with territory, raw materials and sources of energy are considered the five most prized natural resources[12]. All of these are modelled within the ACG. Water is considered both a scarce and vulnerable resource in Africa and the world over, while agriculture is the largest sector dependent on this resource[13 14]. There is a need to balance two partly incompatible pressures in the ACG: human survival and the protection of the resource base on which humans depend[15]. In the ACG agents develop schema in order to manage their resource use but their policies and strategies are frequently undermined by haphazard economic and environmental fluctuations interacting with incomplete or partial information exchanges.

The need to conserve our natural resources, especially water in this instance, requires an understanding of the linkages between the social, political, economic and biophysical dimensions. These have been clearly drawn up by educators such as Lotz-Sisitka and Raven[16] and O'Donoghue[17]. Their presentation of the linkages was used as a framework against which to map the participants understanding of water in the pre and post game questionnaires.

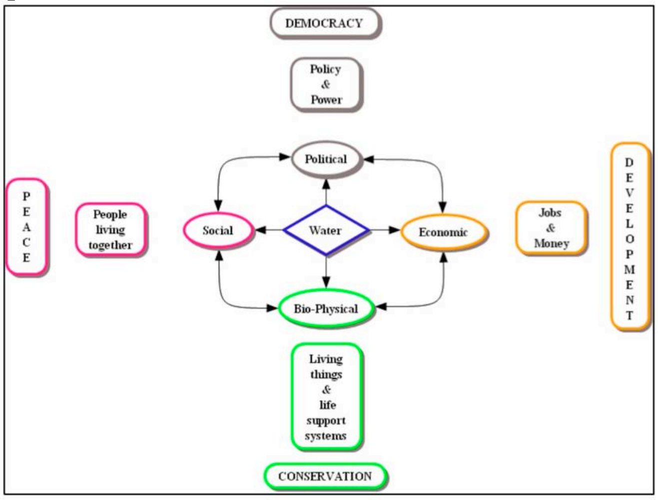

Figure 1. Water positioned within four interrelated dimensions Source: Adapted from O'Donoghue[17]

II. MATERIAL AND METHODS

The ACG was played twice in Finland between 3 and 5 June 2008 at the Finland Futures Research Centre, Turku and at Tammela as part of the Summer School 'systems and simulations'. It was then played a third time with participants at the Rhodes University International Summer School on June 22, 2009. The focus here is on the two Finnish games since the participants' backgrounds and educational contexts are broadly similar. The participants completed a pre and post game questionnaire in which they were asked common sets of questions for their own and the southern African context:

1. Explain how water is used in your local environment.
2. Explain who controls water use.
3. Identify and explain issues and challenges associated with water management.
4. Why do you think these issues have emerged?

In the post game questionnaire they were also asked to comment on:

1. How and whether the game has helped their understanding of water management.
2. Whether they could use insights gained from the game.
3. Recommendations for improving the game.

Participant's responses were categorised into themes which were then allocated into the four main dimensions shown in Figure 1: Political, Economic, Biophysical and Social. We then identified the most statistically significant questions by comparing the pre and post game responses using the Chi Squared test on the combined answers for all three game runs. In this way we identified any change in participants' knowledge as a consequence of playing the game.

At the global level we examined our game managers' spreadsheets which captured the macro-scale economic, trade, population, production, consumption and environmental processes. Additionally we have photographic and video evidence from the group debriefings.

Finally, we present some network level information from the debriefing workshop held after the Turku game. Time constraints meant that we did not have the opportunity to repeat this operation after the game in Tammela.

III. RESULTS

Turku and Tammela Games: Global Processes

Participants in Turku Game Run were well qualified, mostly Finnish, speaking English as a second language and working in the Higher Education field. Nearly two thirds were female and most were aged between 26 and 40 years.

Above average rainfall was experienced during the four year game run and this resulted in low water prices and, in the third yearly cycle, a mild flood that irrigated one field per farm. Food security was not an issue in the game run as a whole due to the doubling of the total yield of rice. Yields increased in line with the total population's growth that resulted in figures which were six percent higher at the end of the game. Urban productivity, however, was hindered by the inefficiency of the industrial sector that was unable to master the input and output processes of the factory system. This resulted in a negative trading balance in the second yearly cycle. The farmers, however, managed to export their surplus rice and so rice exports had tripled by the fourth yearly cycle resulting in an overall favourable trading balance in years three and four. Debt from building the dam remained an issue for the government until the bank was nationalized and so eliminating all relevant debt. Money that would have been spent on paying back the dam loan was then used to subsidise the farming industry, consequently aiding the production of rice surpluses.

In comparison, the Tammela Game Run participants were mostly female Finnish students who had obtained their second degree and were completing their Masters' degree. The majority of these players spoke English as their second language and played the ACG as part of the summer school programme organised by the Finland Futures Research Centre.

Although rainfall remained constant throughout the game it was considerably less than in the Turku game run. Total population increased by 15% over the four year game period and this resulted in rice consumption exceeding rice production throughout the game. Farmers therefore needed to secure agricultural water for irrigation and, as a result, more agricultural and domestic water was issued by the government than industrial water. The peasant farmers formed a commune that allowed them to share their limited resources and to meet the demand for food and water. Since peasant farmers were working together as a group their negotiations with government were effective in procuring subsidies. This left the other game players in the rural sector, such as the commercial farmers and the trader, without government aid forcing them to consider alternative income strategies. One such strategy included allowing children to starve to death as they had become a liability. In the urban sector the government initially focused industrial support on getting sustainable sources of water installed before the industrial production process was properly understood. This resulted in a trading balance that fluctuated between extreme positive and negative balances. In terms of urban productivity, imports significantly decreased throughout the game while exports increased. Although food security was sustainable, factories were not reliably run and this contributed to the fluctuating trading balance.

Turku and Tammela Games: Local Processes.

The following short sections examine each of the four questions with highly significant Chi Squared values (probability >0.001).

For their own context: how is water used in your local environment? (Chi-Square 35.67)

Comparison of the pre- and post- game responses showed that in both the Turku and Tammela game runs participants identified the Economic and Social Dimensions as playing a significant role in water use in their own environment. In Turku participants' post-game questionnaires had an increased emphasis on the Economic where responses rose from 44 to 54%. The Political declined from 16 to 8%. In Tammela there was a very major switch from the Political Dimension to the Social, the Political declined from 44 to 8% whilst the Social rose from 5 to 40%. Within these dimensions there were far more repeated themes in the Turku game run (11) than the Tammela (six) game run. For both game runs these themes included a focus on the liberal use of water for industrial, agricultural, domestic and recreational purposes. In terms of the remaining themes, the Turku game run had five pre-game themes that included a focus on geographical location as a determinant for water use. The Tammela game run had seven pre-game themes which acknowledged that while water was cheap, available and run by water companies in urban areas, the countryside experiences water shortages.

The Turku and Tammela game runs both had post-game themes that included acknowledgement of taking water for granted in the past and expressed a renewed sense of appreciation for well managed and available water. The Turku participants had shifted their awareness from geographical location as a determinant for water use to being appreciative of water that was well managed and available while the Tammela participants had shifted from knowing that water was cheap and available to admitting that these aspects had been taken for granted and they would be more appreciative in the future.

For the southern African context: please identify and explain what issues and challenges, if any, are associated with water management. (Chi-Square 25.21)

For both the Turku (52%) and Tammela (56%) game runs the Political Dimension, as opposed to the Economic Dimension identified above, received the highest response rates in the pre-game questionnaires. This was maintained in the post-game questionnaire with very minor changes. The Biophysical Dimension declined in both game runs from 20 to 13% in Turku and from 24 to 22% in Tammela. The Economic Dimension became more important, however, increasing sharply from 4 to 23% in Turku and less spectacularly from 15 to 19% in Tammela.

Themes repeated included climate change, droughts and pollution. New themes in Turku can be grouped under *vulnerability,* focusing on the political, economic, social and biophysical aspects that drastically impact on survival. Also there were themes categorised as *future considerations* that make note of significant political, economic, social and biophysical aspects that need to be addressed. The Tammela post-game themes can also be grouped but this time into four sub-headings: *government regulated issues*, *natural resources*, *ability to work together* and *other*. In addition, themes tended to acknowledge practical issues and challenges, which can account for the heightened sense of personalisation and urgency in the post-game themes, whereas the pre-game themes seem more abstract, hierarchical and devoid of agency.

For the southern African context: how is water used in the southern African environment? (Chi-Square 20.50)

This question was related to issues and challenges in the southern African context. For the Turku game run the Economic Dimension dominated in the pre- and post-game questionnaires (41% and 56%). This was followed by the Social Dimension (24% and 22%). In Tammela the Political Dimension had the highest pre-game response rate (53%) but this declined sharply in the post-game questionnaires to 2%. The Economic Dimension went up from 33 to 65% and the Social from 3 to 32%.

The Turku pre-game themes focused on the *use of water for agriculture and industry*, that *water is scarce* and *used sparingly in both social and domestic contexts* while the Tammela pre-game themes focused on access, be it due to economic, historical or infrastructural and political reasons. The Turku post-game themes focused on how expensive and important water is for survival as well as that *chance plays a significant role in survival strategies*. The Tammela post-game themes included a focus on the participants' immediate domestic surroundings and non-immediate surroundings: government management and the use of water as a trading commodity. In addition, there was a heightened sense of urgency and perhaps desperation since participants realised through playing the game that water is crucial for survival. There was a noticeable shift between the pre- and post- questionnaires from the use of water in an immediate geographical context to include non-immediate uses as well as the acknowledgement that water is important for survival.

For the southern African context: who controls water? (Chi-Square 15.89)

In both the Turku and Tammela game runs the Political Dimension received the highest response rates for the pre- and post-game questionnaires. Political agents, and the government control of water were important common themes. In Turku the Political Dimension increased from 48 to 59% as there was a shift away from the Other Dimension into the Political and also, as mentioned below, into the Biophysical. In Tammela the Political responses increased from 68 to 83%, this was matched by a corresponding decline in the Economic from 24 to 13% and the Social from 5 to 0%.

In the Turku game run participants' opinions of water control changed from ownership and management, as agents of control, to Biophysical aspects, pricing, misinformation and complexity. This infers that participants had acknowledged the interconnected impacts of water control. Participants from the Tammela game run showed a shift in their understanding of water control from a general to a more centralised focus including all environmental dimensions and incorporating economic agents and reasons.

IV. DISCUSSION AND CONCLUSIONS

The section above has shown that the two games had different global processes: environmentally, socially, economically and politically. The game participants' understanding of the role of water, water management and water issues was clearly impacted on through playing the game though different dimensions of water were highlighted in the two game runs. As a Complex Adaptive System this was to be expected. The participants learned more about water management and sustainable resource use but this was with reference to their own experience and pre-existing understanding. As such we cannot expect to derive any single lesson from playing these games.

What we can do, however, is examine the participants' view of the interconnections in the environmental dimensions of water. This can be done for the Turku game run by looking at the graphic drawn during the debriefing (Figure 2). There is a quite obvious focus on the connectivity of society. There was strong social cohesion in the Finland games, with the political arena and economic realities which the game's rules promote.

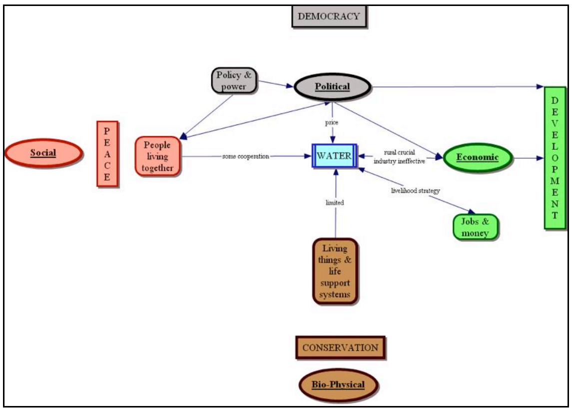

Figure 2. Dimensions of water workshopped with Turku participants.

Unfortunately there was not the opportunity to debrief the Tammela participants in the same way and so there is no direct comparison.

Simulation games such as the African Catchment Game are successful methods through which to enhance our understanding of the role of key natural resources. The Finland game runs placed an emphasis on water but there were many other aspects of sustainable resource usage which the game models. Each game run produced different trajectories but our educational and methodological approach is designed to enrich each individual's own understanding.

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