Human Agency and Learning
A Computer-based Exploration of Sustainable Water Management

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Keywords: Game-based and Simulation-based Learning, Higher Order Thinking Skills, Immersive Learning and Multimedia Applications, Educating the Educators.

Abstract: Hydrological systems provide instructive examples of systems that have both human and natural components. The computer-based learning experience we are designing makes use of maps, models and a game-like experience to introduce learners to sustainability issues in a local watershed. We start with established principles of learning theory, like the idea that human beings learn best when they can act on the world (in this case a digital world), and that role-playing can enhance student engagement in the learning process. However, the paper argues that designers of computer-based learning experiences can benefit from richer models of human agency. Role theory, in particular, provides valuable resources for designers who wish to incorporate different aspects of human agency into the gaming experience.

1 INTRODUCTION

Research has demonstrated that learners often have difficulty dealing with complex systems: they tend to focus on visible at the expense of invisible aspects of systems; and they engage in atomistic thinking rarely appreciating the importance of part/whole relationships (Hmelo-Silver et al., 2015: 9-10). The challenges of complexity are especially acute when systems involve a combination of natural and human components. Yet it is precisely such human/nature interactions that learners will need to understand if they are to meet the challenges of environmental sustainability that loom so large in the contemporary world (Selman, 2012).

The purpose of this position paper is to outline a computer-based strategy for introducing learners to complex human/nature interactions. At the core of the strategy is a game-like experience that allows learners to experience for themselves the challenges associated with managing a basic natural resource: in this case, water. It is argued that when dealing with complexity it makes sense to draw on the insights of major theorists like Piaget and Vygotsky who insisted that to learn effectively human beings must have opportunities to act on and in the world (Cavicchi, 2006; Freeman et al., 2014: 4810, Kozulin, 2001; Lourenco, 2012).

In this paper, this fundamental insight is taken one step further. Drawing on role theory (Biddle 1979, 1986) and recent explorations of the nature of human agency (Archer, 2000, 2012; Frankfurt, 1988; Martin, 2010), some of the processes that unfold as human beings act on and in the world are identified. It makes sense to view human agents in relation to social roles, and this is the basic idea that informs the role playing experiences one encounters in computer games designed for educational purposes (Katsaliaki and Mustafee, 2012: 9-10).

However, it is important to recognize that the traditional model of the human being as a role playing agent is not without flaws. Occupants of roles seek out new knowledge, realizing that reliable knowledge is crucial to enacting roles effectively. Moreover, role-playing may involve role-making, critical thinking about roles. This critical thinking may take the form of internal deliberative processes as persons struggle to remake roles in response to emerging concerns and commitments. But it may also involve processes of dialogue and collaboration.among the occupants of different roles. The challenge is to find ways to incorporate some of these real complexities of human agents into the role playing activities that learners encounter as they participate in computer-based learning. The objectives of this paper are twofold: to outline a richer model of human agency; and to show how this model can be used to design a computer-based learning experience.

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Human Agency and Learning - A Computer-based Exploration of Sustainable Water Management.
DOI: 10.5220/0005487204520456
In *Proceedings of the 7th International Conference on Computer Supported Education* (CSEDU-2015), pages 452-456
ISBN: 978-989-758-107-6

2 A COMPLEX SYSTEM: THE LOCAL WATERSHED

Hydrological systems provide instructive examples of systems that have both human and natural components. The computer-based learning experience we are designing makes use of maps, models and a game-like experience to introduce learners to sustainability issues in a local watershed. The watershed includes many different ecosystems and habitat patches. It bears the marks of previous human uses and continues to support a variety of human uses, both recreational and agricultural. The impact of those human uses on the sensitive ecosystems that compromise the watershed is significant and the watershed must be managed carefully if those ecosystems are to survive.

The critical human component of the watershed consists of a series of dams. Similar dams can be found throughout the region. The climate is semi-arid. While streams and small rivers provide water for agriculture in valley bottoms, they are subject to dewatering in the dry season. Small dams provide a human-made technological solution to this problem allowing those with water permits to regulate the flow of water to their properties.

The dams serve as the most tangible point of contact between the natural processes of the watershed and the human processes associated with agricultural activities. As indicated above, to simulate this point of contact we are creating digital models of the most important dams in the watershed. By turning a digital crank wheels players will be able to influence flow rate and regulate the volume of water diverted to the farmer's fields. This is a critical component of the player's learning experience and is firmly grounded in the basic tenet that human beings learn best when they act on and in the world (in this case a digital world).

The dams are a part of a complex system that incorporates natural and human components. To enable learners to better appreciate the relation between this part of the system and the whole we are linking the water management game to a web site. The web site will include google map representations of the watershed. It will also identify the complex web of overlapping ecosystems that are found in the watershed. Those who visit the web site will be able to see how variables like elevation and precipitation influence the distribution of various plant and animal communities.

Water is, of course, crucial to all of these ecosystems. Salmon use the lower reaches of the river as a spawning ground and there are trout living in the upper reaches of the river and the various smaller lakes located at higher elevations. Water and human decisions about water storage and water flow rates have the potential to impact all of these features of the natural system. The location of the dams in the google map representation will be clearly indicated and this will serve to scaffold the learner's awareness of part/whole relationships.

What about the hidden parts of the system, the parts that, because they are not clearly visible, pose challenges to novice learners? Problems of visibility linked to spatial scale are addressed through the zoom in zoom out function of google maps. By zooming out players can see the whole watershed and see how events that occur in one part of the system (upstream) might affect events elsewhere (downstream). Moreover, we anticipate provide players options that would enable them to 'see' what is happening at smaller spatial scales (the chemical composition of the water that runs off farmer's field, for example).

The fore-mentioned strategies make some progress towards addressing predictable challenges confronting learners who are struggling to understand complex natural systems. However, more is needed to address challenges that arise when a system has natural and human components. What is needed is a richer model of human agency. In the next pages this model is outlined and linked to a computer-based learning experience.

3 HUMAN AGENCY: BUILDING A RICHER MODEL

Central to many forms of computer based learning, especially those where games figure significantly, are role playing activities. In the learning technology we are designing also incorporates role-playing as a key part of the experience. The watershed which provides setting for the learning experience can be viewed from many different perspectives. How an individual understands the challenges of sustainable water management in the area is a function of the different social roles they occupy. A number of roles stand out as especially important from an educational standpoint: elected municipal politician; city planner; farm manager; watershed ecologist; hydrologist, dam safety expert; owners of a fishing resort located upstream; member of the local naturalist club, representative of the federal government's Department of Fisheries and Oceans, etc.

Each of these roles will be associated with a cluster of role- related scripts, and basic issues of what is an acceptable flow rate (either through the dams, or through the outlet located at the point of diversion to the farmer's fields) will be defined by those scripts. This notion of "roles as scripts" makes sense in relation to traditional role theory which portrayed human agents responding in relatively passive ways to the scripts associated with their roles. However, theory of social roles has evolved: many researchers who work in this area now recognize that human actions are best viewed as a combination of role-taking (following scripts) and role-making (Biddle, 1986; Brandle, 2011). The activity of role-making involves a (partially internal) deliberative process where agents seek to reconcile role scripts with their basic values, what they care about (Archer, 2012).

As ideas about sustainability become more widespread, one can imagine the occupants of roles rethinking the scripts associated with their roles to make those scripts more compatible with emerging cultural values like sustainability. So, for example, a learner who is assigned the farmer role might imagine a farmer who is striving to balance the narrowly defined requirement of the farmer script (achieving maximum yield) with environmental concerns (maintaining fish habitat). To be sure, this approach to a role-playing exercise is more complicated than an approach that requires players to simply act out assigned scripts. But it is more congruent with the complexity of real human agents seeking to come to terms with the emerging cultural norms we associate with sustainability.

One way to deal with this complexity is to create a relatively simple version of the game where individuals are assigned the role of a traditional farmer. The responsibility of a traditional famer is to attain maximum yield using a crop selection that generates the greatest profit margins. The traditional farmer will manage water resources to achieve these goals, and the game will be scored to reward crop yields and profit margins.

While this single role version of the game has some merit, there are other options that reflect significant cultural changes in the way water management is understood. No longer is fresh water viewed as an inexhaustible resource. Like many other natural resources, it is finite. Sustainable water management requires collaboration among multiple stakeholders and what some have called a "radical new approach: Integrated Water Resource Management (IWRM)" (Black and King, 2009: 92).

We are working on a version of the game that incorporates key principles of IWRM. This version of the game involves teams of players who seek to enact a range of different roles (such as those identified above). Outstanding performance in this version of the game would involve water management strategies that combine collaborative decision-making with the sharing of specialized knowledge among players.

This collaborative version of game illustrates the way interaction among stakeholders may contribute to role conflict and eventually to role change. It also simulates the real-world mechanisms associated with role change. Research on water management suggests that a key mechanism of role change is the interaction between different stakeholders in a water management system. A recent paper identifies the key principle involved: interaction "requires each member to externalize his/her knowledge, internalize the knowledge of other and then negotiate" (Murgue, Therond and Leenhardt, 2015: 61). The authors of the paper suggest that this collaborative process of externalization/ internalization may help "groups move towards a shared understanding of the problem and a shared representation of potential solutions" (Murgue, Therond and Leenhardt, 2015: 61). The opportunity for dialogue among learners enacting the roles of different stakeholders will be a central part of the learning experience in the collaborative game. We believe it will lead to the kind of critical thinking about roles that contributes to role change and more flexible versions of role enactment.

It is worth pausing at this point to comment on the kinds of knowledge that are relevant to role enactment in the water management game. The watershed that forms the basis of this game is a complex system that includes both natural and human (social) components. Some members of the team will bring knowledge of the natural environment to the knowledge sharing process. For example we anticipate assigning roles like "university ecologist" or "hydrologist" to team members. This will enable team members to appreciate the complex web of ecosystems that intersect in the watershed, and the hydrological cycles that determine the sustainability of those ecosystems.

But effective decision-making about water management involves knowledge of both natural and social environments. The social, legal/regulatory environment, is comprised of water permits, property rights, zoning laws and a range of overlapping government jurisdictions. Traditionally this social complexity led to a fragmented and incoherent approach to decision making in the area of water management. To achieve a more integrated approach, players will need to appreciate both the obstacles and affordances (Gibson, 1979) associated with the social environment in which decisions are made. Agents who are aware of these affordances and obstacles are more likely to pursue their goals effectively.

One way to introduce players to the regulatory environment is to provide simple visual representations that can be accessed as pop ups or through a media library. In addition to these visual representations the player would be read sample documents outlining the various kinds of rules that influence what can and cannot be done in the local watershed. This would include general zoning laws: part of the land in the watershed is provincial park and part is private land; part of the private land is zoned agricultural and must be maintained in this state. Water rights play a critical role in this watershed as in many others. In British Columbia, water rights derive from a legal tradition that construes water as property (Matsui, 2009). Holders of water permits have access to a legally specified volume of water per spatial unit of agricultural land. However the rights of property owners are not absolute: what is permitted in riparian and other protected areas is determined by public authorities. Clearly these key features of the regulatory environment are complicated and we continue to work on strategies for introducing them to learners.

What must be stressed is that in this collaborative version of the game enacting a role involves more than adhering to a script or pursing a narrowly defined objective. In the collaborative version, players must appreciate the perspectives of others, share specialized knowledge, and arrive at water management solutions that balance environmental protection with a broad range of water uses.

4 CONCLUSIONS

Complex systems have hidden components that many learners overlook. Some of what is hidden can be made visible when learners can modify the spatial scale of a map or model as is possible with the zoom in/zoom out function of google earth. However when learners are seeking to understand systems that include natural and social components, conventional ways of representing spatial scale are not enough. What is needed is a richer model of human agency. Such a model should make use of established principles of learning theory like the idea that human beings learn best when they can act on the world (in this case a digital world), or that role-playing can make a crucial contribution to learning.

However, to take full advantage of the role playing component of game design, it is necessary to take into account the challenges associated with role enactment, role conflict, and role change. A role playing scenario that involves collaboration among the occupants of different roles showcases the forms of agency that are valued in modern societies. Outstanding team performance in this context involves understanding the perspectives of others, sharing specialized knowledge, and finding ways to balance competing values. In situations like this, agency becomes a deliberative process, as traditional role expectations are reconciled with emergent cultural norms, and role enactment draws increasingly on diverse forms of specialized knowledge. Role theory, enriched by recent work on the nature of human agency, offers game designers the conceptual resources they will need to represent the social dimensions of complex systems and create more authentic educational experiences for learners.

ACKNOWLEDGEMENTS

I would like to thank my research student Hector Alzade who helped me appreciate the educational value of computer games.

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